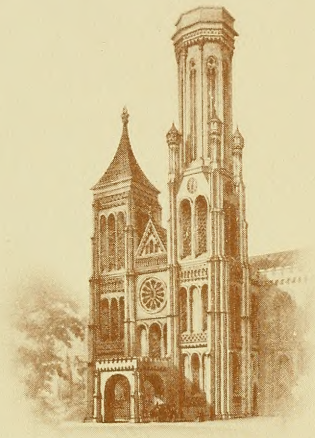
ELISHA HANSON



THE NATIONAL GEOGRAPHIC MAGAZINE

VOLUME I, 1889

WASHINGTON

PUBLISHED BY THE NATIONAL GEOGRAPHIC SOCIETY

1889

OFFICERS OF THE NATIONAL GEOGRAPHIC SOCIETY

1889

GARDINER G. HUBBARD, *President*

HERBERT G. OGDEN
GEO. L. DYER
A. W. GREELY
C. HART MERRIAM
A. H. THOMPSON — *Vice-Presidents*

CHARLES J. BELL, *Treasurer*

HENRY GANNETT
GEORGE KENNAN — *Secretaries*

CLEVELAND ABBE
MARCUS BAKER
ROGERS BIRNIE, JR.
G. BROWN GOODE
C. A. KENASTON
W. B. POWELL
O. H. TITTMANN
JAMES C. WELLING — *Managers*

PRINTERS
TUTTLE, MOREHOUSE & TAYLOR,
NEW HAVEN, CONN.

Vol. I. No. 1.

THE NATIONAL GEOGRAPHIC MAGAZINE.

NATIONAL GEOGRAPHIC SOCIETY
INCORPORATED A.D.1888.

PUBLISHED BY THE

NATIONAL GEOGRAPHIC SOCIETY.

WASHINGTON, D. C.

Price 50 Cents.

CONTENTS.

PRESS OF TUTTLE, MOREHOUSE & TAYLOR, NEW HAVEN, CONN.

ANNOUNCEMENT.

The "National Geographic Society" has been organized "to increase and diffuse geographic knowledge," and the publication of a Magazine has been determined upon as one means of accomplishing these purposes.

It will contain memoirs, essays, notes, correspondence, reviews, etc., relating to Geographic matters. As it is not intended to be simply the organ of the Society, its pages will be open to all persons interested in Geography, in the hope that it may become a channel of intercommunication, stimulate geographic investigation and prove an acceptable medium for the publication of results.

The Magazine is to be edited by the Society. At present it will be issued at irregular intervals, but as the sources of information are increased the numbers will appear periodically.

The National Capital seems to be the natural and appropriate place for an association of this character, and the aim of the founders has been, therefore, to form a National rather than a local society.

As it is hoped to diffuse as well as to increase knowledge, due prominence will be given to the educational aspect of geographic matters, and efforts will be made to stimulate an interest in original sources of information.

In addition to organizing, holding regular fortnightly meetings for presenting scientific and popular communications, and entering upon the publication of a Magazine, considerable progress has been made in the preparation of a Physical Atlas of the United States.

The Society was organized in January, 1888, under the laws of the District of Columbia, and has at present an active membership of about two hundred persons. But there is no limitation to the number of members, and it will welcome both leaders and followers in geographic science, in order to better accomplish the objects of its organization.

October, 1888.

Correspondence with the Society should be addressed to Mr. George Kennan, Corresponding Secretary, No. 1318 Massachusetts Avenue, Washington, D. C.

THE

NATIONAL GEOGRAPHIC MAGAZINE.

Vol. I. 1888. No. 1.

INTRODUCTORY ADDRESS.

By the President, Mr. Gardiner G. Hubbard.

I am not a scientific man, nor can I lay claim to any special knowledge that would entitle me to be called a "Geographer." I owe the honor of my election as President of the National Geographic Society simply to the fact that I am one of those who desire to further the prosecution of geographic research. I possess only the same general interest in the subject of geography that should be felt by every educated man.

By my election you notify the public that the membership of our Society will not be confined to professional geographers, but will include that large number who, like myself, desire to promote special researches by others, and to diffuse the knowledge so gained, among men, so that we may all know more of the world upon which we live.

By the establishment of this Society we hope to bring together (1) the scattered workers of our country, and (2) the persons who desire to promote their researches. In union there is strength, and through the medium of a national organization, we may hope to promote geographic research in a manner that could not be accomplished by scattered individuals, or by local societies; we may also hope—through the same agency—to diffuse the results of geographic research over a wider area than would otherwise be possible.

The position to which I have been called has compelled me to become a student. Since my election I have been trying to learn the meaning of the word "geography," and something of the history of the science to which it relates. The Greek origin of the word (*γὴ*, the earth, and *γραφη*, description) betrays the source from which we derived the science, and shows that it relates to a description of the earth. But the "earth" known to the Greeks was a very different thing from the earth with which we are acquainted.

To the ancient Greek it meant land—not all land, but only a limited territory, in the centre of which he lived. His earth comprised simply the Persian Empire, Italy, Egypt and the borders of the Black and Mediterranean seas, besides his own country. Beyond these limits, the land extended indefinitely to an unknown distance—till it reached the borders of the great ocean which completely surrounded it.

To the members of this society the word "earth" suggests a very different idea. The term arouses in our minds the conception of an enormous globe suspended in empty space, one side in shadow and the other bathed in the rays of the sun. The outer surface of this globe consists of a uniform, unbroken ocean of air, enclosing another more solid surface (composed partly of land and partly of water), which teems with countless forms of animal and vegetable life. This is the earth of which geography gives *us* a description.

To the ancients the earth was a flat plain, solid and immovable, and surrounded by water, out of which the sun rose in the east and into which it set in the west. To them "Geography" meant simply a description of the lands with which they were acquainted.

Herodotus, who lived about the year 450 B. C., transmitted to posterity an account of the world as it was known in his day. We look upon him as the father of geography as well as of history. He visited the known regions of the earth, and described accurately what he saw, thus laying the foundations of comparative geography.

About 300 years B. C., Alexander the Great penetrated into hitherto unknown regions, conquered India and Russia, and founded the Macedonian Empire. He sent a naval expedition to explore the coasts of India, accompanied by philosophers or learned men, who described the new countries discovered and the character of their inhabitants. This voyage may be considered as originating the science of Political Geography, or the geography of man.

About the year 200 B. C., Eratosthenes of Cyrene, the keeper of the Royal Library at Alexandria, became convinced, from experiments, that the idea of the rotundity of the earth, which had been advanced by some of his predecessors, was correct, and attempted to determine upon correct principles its magnitude. The town of Cyrene, on the river Nile, was situated exactly under the tropic, for he knew that on the day of the summer solstice, the sun's rays illuminated at noon the bottom of a deep well in that city. At Alexandria, however, on the day of the summer solstice, Eratosthenes observed that the vertical finger of a sun-dial cast a shadow at noon, showing that the sun was not there exactly overhead. From the length of the shadow he ascertained the sun's distance from the zenith to be 7° 12′, or one-fiftieth part of the circumference of the heavens; from which he calculated that if the world was round the distance between Alexandria and Cyrene should be one-fiftieth part of the circumference of the world. The distance between these cities was 5000 stadia, from which he calculated that the circumference of the world was fifty times this amount, or 250,000 stadia. Unfortunately we are ignorant of the exact length of a stadium, so we have no means of testing the accuracy of his deduction. He was the founder of Mathematical Geography; it became possible through the labors of Eratosthenes to determine the location of places on the surface of the earth by means of lines corresponding to our lines of latitude and longitude.

Claudius Ptolemy, in the second century of the Christian era, made a catalogue of the positions of plans as determined by Erastosthenes and his successors, and with this as his basis, he made a series of twenty-six maps, thus exhibiting, at a glance, in geographical form, the results of the labors of all who preceded him. To him we owe the art of map-making, the origination of Geographic Art.

We thus see that when Rome began to rule the world, the Greeks had made great progress in geography. They already possessed Comparative, Political and Mathematical Geography, and Geographic Art, or the art of making maps.

Then came a pause in the progress of geography.

The Romans were so constantly occupied with the practical affairs of life, that they paid little attention to any other kind of geography than that which facilitated the administration of their empire. They were great road-builders, and laid out highways from Rome to the farthest limits of their possessions. Maps of their military roads were made, but little else. These exhibited with accuracy the less and greater stations on the route from Rome to India, and from Rome to the further end of Britain.

Then came the decline and fall of Rome, and with it the complete collapse of geographical knowledge. In the dark ages, geography practically ceased to exist. In the typical map of the middle ages, Jerusalem lay in the centre with Paradise on the East and Europe on the West. It was not until the close of the dark ages that the spirit of discovery was re-awakened. Then the adventurous Northmen from Norway and Sweden crossed the ocean to Iceland.

From Iceland they proceeded to Greenland and even visited the main-land of North America about the year 1000 A. D., coasting as far south as New England; but these voyages led to no practical results, and were forgotten or looked upon as myths, until within a few years. For hundreds of years geography made but little advance—and the discoveries of five centuries were less than those now made in five years. In the fourteenth or fifteenth century, the mariner's compass was introduced into Europe from China, and it then became possible to venture upon the ocean far out of sight of land. Columbus instead of coasting from shore to shore like the ancient Northmen, boldly set sail across the Atlantic. To many of his contemporaries it must have seemed madness to seek the East by thus sailing towards the West, and we need hardly wonder at the opposition experienced from his crew. The rotundity of the earth had become to him an objective reality, and in sublime faith he pursued his westward way. Expecting to find the East Indies he found America instead. Five centuries had elapsed since the Northmen had made their voyages to these shores—and their labors had proved to be barren of results. The discovery of Columbus, however, immediately bore fruit. It was his genius and perseverance alone that gave the new world to the people of Europe, and he is therefore rightfully entitled to be called the discoverer of America. His discovery was fraught with enormous consequences, and it inaugurated a new era for geographic research. The spirit of discovery was quickened and geographic knowledge advanced with a great leap. America was explored ; Africa was circumnavigated. Magellan demonstrated the rotundity of the earth by sailing westward until he reached his starting point. Everywhere —all over the civilized world—the spirit of adventure was aroused. Navigators from England, Holland, France and Spain rapidly extended the boundaries of geographical knowledge, while explorers penetrated into the interior of the new lands discovered. The mighty impetus given by Columbus set the whole world in motion and it has gone on moving ever since with accelerated velocity.

The great progress that has been made can hardly be realized without comparing the famous Borgia map, constructed about one hundred years before the discovery of America, with the modern maps of the same countries ; or Hubbard's map of New England made two hundred years ago, with the corresponding map of to-day. The improvements in map-making originated with Mercator, who, in 1556 constructed his cylindrical projection of the sphere. But it has been only during the last hundred years that great progress has been made. Much yet remains to be done before geographic art can fully accomplish its mission.

The present century forms a new era in the progress of geography—the era of organized research. In 1830, the Royal Geographical Society of England was founded, and it already forms a landmark in the history of discovery. The Paris Society preceded it in point of time, and the other countries of Europe soon followed the example. Through these organizations, students and explorers have been encouraged and assisted, and information systematically collected and arranged. The wide diffusion of geographical knowledge through the medium of these societies and the publicity of the discussions and criticism that followed, operated to direct the current of exploration into the most useful channels. Before organized effort, darkness gave way at every step. Each observer added fresh knowledge to the existing store, without unnecessary duplication of research. The reports of discoveries were discussed and criticized by the societies, and the contributions of all were co-ordinated into one great whole.

America refuses to be left in the rear. Already her explorers are in every land and on every sea. Already she has contributed her quota of martyrs in the frozen north, and has led the way into the torrid regions of Africa. The people of Europe, through Columbus, opened up a new world for us ; and we, through Stanley, have discovered a new world in the old, for them.

Much has been done on land—little on the other three-quarters of the earth's surface. But here America has laid the foundations of a new science,—the Geography of the Sea.

Our explorers have mapped out the surface of the ocean and discovered the great movements of the waters. They have traced the southward flow of the Arctic waters to temper the climate of the torrid zone. They have followed the northward set of the heated waters of the equator and have shown how they form those wonderful rivers of warm water that flow, without walls, through the colder waters of the sea, till they strike the western shores of Europe and America, and how they render habitable the almost Arctic countries of Great Britian and Alaska. They have even followed these warm currents further and shown how they penetrate the Arctic Ocean to lessen the rigors of the Arctic cold. Bravely, but vainly, have they sought for that *ignis fatuus* of explorers—the open polar sea—produced by the action of the warm waters from the south.

American explorers have sounded the depths of the ocean and discovered mountains and valleys beneath the waves. They have found the great plateaus on which the cables rest that bring us into instantaneous communication with the rest of the world. They have shown the probable existence of a vast submarine range of mountains, extending nearly the whole length of the Pacific Ocean—mountains so high that their summits rise above the surface to form islands and archipelagoes in the Pacific. And all this vast region of the earth, which, a few years ago, was considered uninhabitable on account of the great pressure, they have discovered to be teeming with life. From the depths of the ocean they have brought living things, whose lives were spent under conditions of such pressure that the elastic force of their own bodies burst them open before they could be brought to the sur face; living creatures whose self-luminous spots supplied them with the light denied them in the deep abyss from which they sprang—abysses so deep that the powerful rays of the sun could only feebly penetrate to illuminate or warm.

The exploring vessels of our Fish Commission have discovered in the deep sea, in one single season, more forms of life than were found by the Challenger Expedition in a three years' cruise. Through their agency, we have studied the geographical distribution of marine life ; and in our marine laboratories, explorers have studied the life history of the most useful forms.

The knowledge gained has enabled us to breed and multiply at will ; to protect the young fish during the period of their infancy—when alone they are liable to wholesale destruction—finally to release them in the ocean, in those waters that are most suitable to their growth. The fecundity of fish is so great, and the protection afforded them during the critical period of their life so ample, that it may now be possible to feed the world from the ocean and set the laws of Matthews at defiance. Our geographers of the sea have shown that an acre of water may be made to produce more food for the support of man than ten acres of arable land. They have thrown open to cultivation a territory of the earth constituting three-quarters of the entire surface of the globe.

And what shall we say of our conquests in that other vast territory of the earth, greater in extent than all the oceans and the lands put together—the atmosphere that surrounds it.

Here again America has led the way, and laid the foundations of a Geography of the Air. But a little while ago and we might have truly said with the ancients "the wind bloweth where it listeth, and we know neither from whence it comes nor whither it goes"; but now our explorers track the wind from point to point and telegraph warnings in advance of the storm.

In this department, the Geography of the Air, we have far outstripped the nations of the world. We have passed the mob-period of research when the observations of multitudes of individuals amounted to little, from lack of concentrated action. Organization has been effected. A Central Bureau has been established in Washington, and an army of trained observers has been dispersed over the surface of the globe, who all observe the condition of the atmosphere according to a pre-concerted plan.

The vessels of our navy and the mercantile marine of our own and other countries have been impressed into the service, and thus our geographers of the air are stationed in every land and traverse the waters of every sea. Every day, at the same moment of absolute time, they observe and note the condition of the atmosphere at the part of the earth where they happen to be, and the latitude and longitude of their position. The collocation of these observations gives us a series of what may be termed instantaneous photographs of the condition of the whole atmosphere. The co-ordination of the observations, and their geographical representation upon a map, is undertaken by a staff of trained experts in the Central Bureau in Washington, and through this organization we obtain a weather-map of the world for every day of the year. We can now study at leisure the past movements of the atmosphere, and from these observations we shall surely discover the grand laws that control aerial phenomena. We shall then not only know, as we do at present, whence comes the wind and whither it goes, but be able to predict its movements for the benefit of humanity.

Already we have attained a useful, though limited, power of prediction.

Our Central Bureau daily collects observations by telegraph from all parts of this continent, and our experts are thus enabled to forecast the probabilities by a few hours. Day by day the results are communicated to the public by telegraph in time to avert disaster to the mariners on our eastern coast, and facilitate agricultural operations in the Eastern and Middle States.

Although many of the predictions are still falsified by events, the percentage of fulfilments has become so large as to show that continued research will in the future give us fresh forms of prediction and increase the usefulness of this branch of science to mankind.

In all departments of geographical knowledge, Americans are at work. They have pushed themselves into the front rank and they demand the best efforts of their countrymen to encourage and support.

When we embark on the great ocean of discovery, the horizon of the unknown advances with us and surrounds us wherever we go. The more we know, the greater we find is our ignorance. Because we know so little we have formed this society for the increase and diffusion of Geographical knowledge. Because our subject is so large we have organized the society into four broad sections: relating to the geography of the land, H. G. Ogden, vice-president ; the sea, J. R. Bartlett, vice-president ; the air, A. W. Greely, vice-president ; the geographic distribution of life, C. H. Merriam, vice-president; to which we have added a fifth, relating to the abstract science of geographic art, including the art of map-making etc., A. H. Thompson, vice-president ; our recording and corresponding secretaries are Henry Gannett and George Kennan.

We have been fortunate indeed to secure as Vice-Presidents men learned in each department, and who have been personally identified with the work of research.

GEOGRAPHIC METHODS IN GEOLOGIC INVESTIGATION.

By W. M. Davis.

OUTLINE.

Definition of Geography and Geology—Geographic Methods in Geology—Hutton and Lyell—Marine deposits explained by existing processes reveal the history of the earth—American Topographers—First Pennsylvania Survey; geographic form as the result of extinct processes—Western Surveys; geographic form explained by existing processes reveals the history of the earth—Deductive Topography—Comparison with Palæontology—Geographic Individuals—Classification according to structure—Ideal cycle of regular development—Interruptions in the Simple Ideal Cycle—Geography needs ideal types and technical terms—Comparison with the biological sciences—Teaching of Geography—The water-falls of Northeastern Pennsylvania as examples of deductive study—Systematic Geography.

The history of the earth includes among many things an account of its structure and form at successive times, of the processes by which changes in its structure and form have been produced, and of the causes of these processes. Geography is according to ordinary definition allowed of all this only an account of the present form of the earth, while geology takes all the rest, and it is too generally the case that even the present form of the earth is insufficiently examined by geographers. Geographic morphology, or topography, is not yet developed into a science. Some writers seem to think it a division of geology, while geologists are as a rule too much occupied with other matters to give it the attention it deserves. It is not worth while to embarrass one's study by too much definition of its subdivisions, but it is clearly advisable in this case to take such steps as shall hasten a critical and minute examination of the form of the earth's surface by geographers, and to this end it may serve a useful purpose to enlarge the limited definition of geography, as given above, and insist that it shall include not only a descriptive and statistical account of the present surface of the earth, but also a systematic classification of the features of the earth's surface, viewed as the results of certain processes, acting for various periods, at different ages, on divers structures. As Mackinder of Oxford has recently expressed it, geography is the study of the present in the light of the past. When thus conceived it forms a fitting complement to geology, which, as defined by the same author, is the study of the past in the light of the present. The studies are inseparable and up to a certain point, their physical aspects may be well followed together, under such a name as physiography. Specialization may then lead the student more to one subject than to the other.

An illustration from human history, where the study of the past and present has a single name, may serve to make my meaning clear in regard to the relation of the two parts of terrestrial history, which have different names. A descriptive and statistical account of a people as at present existing, such as that which our statistical atlas of the last Census gives in outline, corresponds to geography in its ordinary limitation. A reasonable extension of such an account, introducing a consideration of antecedent conditions and events, for the purpose of throwing light on existing relations, represents an expanded conception of geography. The minute study of the rise and present condition of any single industry would correspond to the monographic account of the development of any simple group of geographic forms. On the other hand, history taken in its more general aspects, including an inquiry into the causes and processes of the rise and fall of ancient nations, answers to geology ; and an account of some brief past stage of history is the equivalent of paleography, a subject at present very little studied and seemingly destined always to escape sharp determination. It is manifest that geology and geography thus defined are parts of a single great subject, and must not be considered independently.

History became a science when it outgrew mere narration and searched for the causes of the facts narrated ; when it ceased to accept old narratives as absolute records and judged them by criteria derived from our knowledge of human nature as we see it at present, but modified to accord with past conditions.

Geology became a science when it adopted geographic methods. The interpretation of the past by means of a study of the present proves to be the only safe method of geologic investigation. Hutton and Lyell may be named as the prominent leaders of this school and if we admit a reasonable modification of their too pronounced uniformitarianism, all modern geologists are their followers. The discovery of the conservation and correlation of energy gives additional support to their thesis by ruling out the gratuitous assumption of great results from vague causes. Causes must be shown to be not only appropriate in quality, but sufficient in quantity before they can be safely accepted. But the geographic argument as expounded by the English school deals almost entirely with processes and neglects a large class of results that follow from these processes. Much attention is given to the methods of transferring the waste of the land to the sea and depositing it there in stratified masses, from which the history of ancient lands is determined. But the forms assumed by the wasting land have not been sufficiently examined. It was recognized in a general way that land forms were the product of denudation, but the enormous volume of material that had been washed off of the lands was hardly appreciated, and the great significance of the forms developed during the destruction of the land was not perceived.

Hutton says a little about the relation of topography to structure; Lyell says less. The systematic study of topography is largely American. There is opportunity for it in this country that is not easily found in Europe. The advance in this study has been made in two distinct steps: first, in the East about 1840; second, in the West about 1870. The first step was taken in that historic decade when our early State surveys accomplished their great work. The Pennsylvania surveyors then developed topography into a science, as Lesley tells us so eloquently in his rare little book "Coal and its Topography," 1856, which deserves to be brought more to the attention of the younger geographers and geologists of to-day. It presents in brief and picturesque form the topographical results of the first geological survey of Pennsylvania. It shows how Lesley and the other members of that survey "became not mineralogists, not miners, not learned in fossils, not geologists in the full sense of the word, but topographers, and topography became a science and was returned to Europe and presented to geology as an American invention. The passion with which we studied it is inconceivable, the details into which it leads us were infinite. Every township was a new monograph." (p. 125.) Some of the finest groups of canoes and zigzags developed on the folded beds of the Pennsylvania Appalachians are illustrated from studies made by Henderson, Whelpley and McKinley, and they certainly deserve the most attentive examination. I often feel that they have been of the greatest assistance in my own field work, especially in the efforts I have made to discover the structural arrangement of the Triassic lava sheets in the Connecticut valley. But although the intricacies of Appalachian topography were then clearly seen to depend on the complications of Appalachian structure, the process of topographic development was not at that time discovered. "The only question open to discussion is," says Lesley, "whether this planing down of the crust to its present surface was a secular or an instantaneous work" (p. 132), and he decides in favor of the latter alternative. He adds, that to the field worker, "The rush of an ocean over a continent . . . . . leads off the whole procession of his facts, and is indispensable to the exercise of his sagacity at every turn" (p. 166). "The present waters are the powerless modern representatives of those ancient floods which did the work" (p. 151).

It is not the least in any spirit of disparagement that I quote these cataclysmic views, now abandoned even by their author. Great generalizations are not often completed at a single step, and it is enough that every effort at advance should have part of its movement in the right direction. What I wish to show is that topographic form was regarded in the days of our eastern surveys, even by our first master of American topography, as a completed product of extinct processes. Topography revealed structure, but it did not then reveal the long history that the structure has passed through. The anticlinal valleys, hemmed in by the even-topped sandstone mountains of middle Pennsylvania, were found to tell plainly enough that a vast erosion had taken place, and that the resulting forms depended on the structure of the eroded mass, but it was tacitly understood that the land stood at its present altitude during the erosion. The even crest lines of the mountains and the general highland level of the dissected plateau farther west did not then reveal that the land had stood lower than at present during a great part of the erosion, and thus the full lesson of the topography was not learned. The systematic relation of form to structure, base level and time; the change of drainage areas by contest of headwaters at divides; the revival of exhausted rivers by massive elevations of their drainage areas: all these consequences of slow adjustments were then unperceived. In later years there seems to be a general awakening to the great value of these principles, which mark the second stage in the advance of scientific topography, referred to above.

It is not easy to sketch the history of this awakening. Ramsay years ago contributed an element in his explanation of plains of marine denudation ; Jukes opened the way to an understanding of cross valleys ; Newberry excluded fractures from the production of the most fracture-like of all water ways ; and our government surveyors in the western territories have fully developed the all important idea of base level, of which only a brief and imperfect statement had previously been current. I cannot say how far European geographers and geologists would be willing to place the highest value on the last named element ; to me it takes the place of Lesley's ocean flood, in leading off the whole procession of outdoor facts. It is indispensable at every turn. Recently, mention should be made of Löwl, of Prague, who has done so much to explain the development of rivers, and of McGee, who has explicitly shown that we must "read geologic history in erosion as well as in deposition."

If it be true that the greater part of this second advance is American like the first, it must be ascribed to the natural opportunities allowed us. The topographers of the Appalachians had a field in which one great lesson was repeated over and over again and forced on their attention. The patchwork structure of Europe gave no such wide opportunity. The surveyors of the western territories again found broad regions telling one story, and all so plainly written that he must run far ahead who reads it. It is to this opportunity of rapid discovery and interpretation that Archibald Geikie alludes in the preface to the recent second edition of his charming volume on the "Scenery of Scotland." He says that since the book first appeared he has seen many parts of Europe, "but above all it has been my good fortune to have been able to extend the research into western America, and to have learned more during my months of sojourn there than during the same number of years in the Old Country." (p. vii.)

Our position now is, therefore, while structure determines form as our earlier topographers taught, and while form-producing processes are slow, as had been demonstrated by the English geologists, that the sequence of forms assumed by a given structure during its long life of waste is determinate, and that the early or young forms are recognizably different from the mature forms and the old forms. A young plain is smooth. The same region at a latter date will be roughened by the channeling of its larger streams and by the increase in number of side branches, until it comes to "maturity," that is to the greatest variety or differentiation of form. At a still later date the widening of the valleys consumes the intervening hills, and the form becomes tamer, until in "old age" it returns to the simple plain surface of "youth." Young mountains possess structural lakes and are drained largely by longitudinal valleys ; old mountains have no such lakes and have transverse drainage, formed as the growing headwaters of external streams lead out much water that formerly followed the longitudinal valleys. Young rivers may have falls on tilted beds, but such are short lived. Falls on horizontal beds are common and survive on the headwater branches of even mature rivers. All falls disappear in old rivers, provided they are not resuscitated by some accident in the normal, simple cycle of river life. The phases of growth are as distinct as in organic forms. As this idea has grown in my mind from reading the authors above named, geography has gained a new interest. The different parts of the world are brought into natural relations with one another ; the interest that change, growth and life had before given to the biologic sciences only, now extends to the study of inorganic forms. It matters not that geographic growth is destructive ; it involves a systematic change of form from the early youth to the distant old age of a given structure, and that is enough. It matters not that the change is too slow for us to see its progress in any single structure. We do not believe that an oak grows from an acorn from seeing the full growth accomplished while waiting for the evidence of the fact, but because partly by analogy with plants of quicker development, partly by the sight of oaks of different ages, we are convinced of a change that we seldom wait to see. It is the same with geographic forms. We find evidence of the wasting of great mountains in the wasting of little mounds of sand ; and we may by searching find examples of young, mature and old mountains, that follow as well marked a sequence as that formed by small, full grown and decaying oaks. If the relative positions of the members in the sequence is not manifest at first, we have the mental pleasure of searching for their true arrangement. The face of nature thus becomes alive and full of expression, and the conception of its change becomes so real that one almost expects to see the change in successive visits to one place.

Now consider the deductive application of this principle. Having recognized the sequence of forms developed during the wasting life of a single structure, reverse the conception and we have a powerful geographic method for geologic investigation. On entering a new country, apply there the principles learned from the inductive study of familiar regions, and much past history is revealed; the age of mountains may be deduced from their form as well as from their rocks; the altitudes at which a district has stood may be determined by traces of its old base levels, of which we learn nothing from the ordinary routine of geologic observation, that is, from a study of the structure and age of the rocks themselves. The principle is commonly employed nowadays, but its methods are not formulated, and its full value is hardly yet perceived. Heim has found traces of successive elevations in the Alps, proved by incipient base levels at several consistent altitudes on the valley slopes. Newberry, Powell and Dutton have worked out the history of the plateau and cañon region from its topography; Chamberlin and Salisbury write of the young and old topographic forms of the drift-covered and the driftless areas in Wisconsin; LeConte and Stephenson have interpreted chapters in the history of California and Pennsylvania from the form of the valleys. Recently McGee has added most interesting chapters to the history of our middle Atlantic slope, in an essay that gives admirable practical exposition of the geographic methods. In the light of these original and suggestive studies one may contend that when geographic forms in their vast variety are thus systematically interpreted as the surface features of as many structures, belonging to a moderate number of families and having expression characteristic of their age and accidents, their elevation and opportunity, then geography will be for the wasting lands what palæontology has come to be for the growing ocean floors.

An interesting comparison may be drawn here. Fossils were first gathered and described as individual specimens, with no comprehension of their relationships and their significance. It was later found that the fossils in a certain small part of the world, England—that wonderful epitome of geologic history—were arranged in sequences in the bedded rocks containing them, certain groups of forms together, successive groups in shelves, as it were, one over another. Then it was discovered that the local English scale had a wider application, and finally it has come to be accepted as a standard, with certain modifications, for the whole world. The exploring geologist does not now wait to learn if a formation containing trilobites underlies another containing ammonites, but on finding the fossils in the two, confidently and as far as we know correctly concludes that such is their relative position. Thus the sequence of submarine processes is made out by the sequence of organic forms. In brief, palæontology has passed largely from the inductive to the deductive stage.

The geographer first regarded the features of the land as completed entities, with whose origin he was in no wise concerned. Later it was found that some conception of their origin was important in appreciating their present form, but they were still regarded as the product of past, extinct processes. This view has been in turn displaced by one that considers the features of the land as the present stage of a long cycle of systematically changing forms, sculptured by processes still in operation. Now recognizing the sequence of changing forms, we may determine the place that any given feature occupies in the entire sequence through which it must pass in its whole cycle of development. And then reversing this conception we are just beginning to deduce the past history of a district by the degree of development of its features. Geography is, in other words, entering a deductive stage, like that already reached by palæontology.

The antecedent of deductive topography is the systematic study of land geography. The surface of the land is made up of many more or less distinct geographic individuals, every individual consisting of a single structure, containing many parts or features whose expression varies as the processes of land sculpture carry the whole through its long cycle of life. There is endless variety among the thousands of structures that compose the land, but after recognizing a few large structural families, the remaining differences may be regarded as individual. In a given family, the individuals present great differences of expression with age, as between the vigorous relief of the young Himalaya and the subdued forms of the old Appalachians; or with elevation over base level, as between the gentle plain of the low Atlantic coast and the precocious high plateaus of the Colorado river region; or with opportunity, as between the last named plateaus with exterior drainage and the high plains of the Great Basin, whose waters have no escape save by evaporation or high level overflow; or with complexity of history, as between the immature, undeveloped valleys of the lava block country of southern Oregon, and the once empty, then gravel-filled, and now deeply terraced inner valleys of the Himalaya. When thus studied, the endless variety of the topography will be considered in its proper relations, and it will not seem as hopeless as it does now to gain a rational understanding and appreciation of geographic morphology.

We should first recognize the fact that a geographic individual is an area, large or small, whose surface form depends on a single structure. Boundaries may be vague, different individuals may be blended or even superposed, but in spite of the indefiniteness, the attempt to sub-divide a region into the individuals that compose it will be found very profitable. In a large way the Appalachian plateau is an individual; the Adirondacks, the terminal moraine of the second glacial epoch are others. In a small way, a drumlin, a fan delta, a mesa, are individuals. The linear plateaus of middle Pennsylvania are hybrids between the well-developed linear ridges of the mountains farther east and the irregular plateau masses farther west.

A rough classification of geographic individuals would group them under such headings as plains, plateaus, and rough broken countries of horizontal structure; mountains of broken, tilted or folded structure, generally having a distinct linear extension; volcanoes, including all the parts from the bottom of the stem or neck, up to the lateral subterranean expansions known as laccolites, and to the surface cones and flows; glacial drift; wind drift. The agents which accomplished the work of denudation are also susceptible of classification: rivers according to the arrangement of their branches, and their imperfections in the form of lakes and glaciers. The valleys that rivers determine may be considered as the converse of the lands in which they are cut; and the waste of the land on the way to the sea is susceptible of careful discrimination: local soil, talus, alluvial deposits, fan cones and fan deltas, flood plains and shore deltas. Their variations dependent on climatic conditions are of especial importance. The structures formed along shore lines are also significant. This list is intentionally brief, and the lines between its divisions are not sharply drawn. It undoubtedly requires discussion and criticism before adoption. It differs but slightly from the common geographic stock in trade, but for its proper application it requires that the geographer should be in some degree a geologist.

The changes in any geographic individual from the time when it was offered to the destructive forces to the end of its life, when it is worn down to a featureless base level surface, are worthy of the most attentive study. The immaturity of the broken country of southern Oregon, as compared with the more advanced forms of the Basin ranges, is a case in hand. The Triassic formation of the Connecticut valley is in some ways of similar structure, being broken by long parallel faults into narrow blocks or slabs, every block being tilted from its original position. Russell's description of the blocks in southern Oregon would apply nicely to those in Connecticut, except that the former have diverse displacements, while the latter all dip one way; but the Connecticut individual has, I feel confident, passed through one cycle of life and has entered well on a second; it has once been worn down nearly to base level since it was broken and faulted, and subsequent elevation at a rather remote period has allowed good advance in a repetition of this process. The general uniformity in the height of its trap ridges and their strong relief above the present broad valley bottom, require us to suppose this complexity of history. A given structure may therefore pass through two or more successive cycles of life, and before considering the resulting composite history in its entirety, it would be best to examine cases of simple development in a single cycle. After this is accomplished, it would be possible to recognize the incomplete partial cycles through which a structure has passed, and to refer every detail of form to the cycle in which it was produced.

The most elementary example that may be chosen to illustrate a simple cycle of geographic life is that of a plain, elevated to a moderate height above its base level. The case has already been referred to here and is given in more detail in an article printed in the proceedings of the American Association for the Advancement of Science, for 1884, to which I would now refer. When the succession of forms there described as developed at a given elevation over base level is clearly perceived, the occurrence of forms dependent on two different base levels in a single region can easily be recognized. The most striking example of such a complex case that I know of is that of the high plateaus of Utah, as described by Dutton. Northern New Jersey presents another example less striking but no less valuable: the general upland surface of the Highlands is an old base level, in which valleys have been cut in consequence of a subsequent elevation. The plateau developed on the tilted Triassic beds about Bound Brook is a second base level, cut during a halt in the rise from the previous lower stand of the land to its present elevation. There is a parable that illustrates the principle here presented.

An antiquary enters a studio and finds a sculptor at work on a marble statue. The design is as yet hardly perceptible in the rough cut block, from which the chisel strikes off large chips at every blow ; but on looking closer the antiquary discovers that the block itself is an old torso, broken and weather beaten, and at once his imagination runs back through its earlier history. This is not the first time that the marble has lain on a sculptor's table, and suffered the strong blows of the first rough shaping. Long ago it was chipped and cut and polished into shape, and perhaps even set up in its completed form in some garden, but then it was neglected and badly used, thrown over and broken, till its perfect shape was lost, and it was sold for nothing more than a marble block, to be carved over again if the sculptor sees fit. Now it just beginning its second career. We may find many parallels to this story in the land about us, when we study its history through its form. The sequence of events and consequently of forms is so apparent here that no one could have difficulty in interpreting history from form, and it shall come to be the same in geography. The gorge of the Wissahickon through the highland northwest of Philadelphia can have no other interpretation than one that likens it to the first quick work of the sculptor on the old torso.

An essential as well as an advantage in this extension of the study of geography will be the definition of types and terms, both chosen in accordance with a rational and if possible a natural system of classification. Types and terms are both already introduced into geographic study, for its very elements present them to the beginner in a simple and rather vague way : mountains are high and rough ; lakes are bodies of standing water, and so on. It is to such types and terms as these that every scholar must continually return as he reads accounts of the world, and it is to be regretted that the types are yet so poorly chosen and so imperfectly illustrated, and that the terms are so few and so insufficient. Physical geography is particularly deficient in these respects, and needs to be greatly modified in the light of the modern advance of topography General accounts of continental homologies of course have their interest and their value, but they are of the kind that would associate whales with fishes and bats with birds. The kind of reform that is needed here may be perceived from that which has overtaken the biological sciences. The better teaching of these subjects lays representative forms before the student and requires him to examine their parts minutely. The importance of the parts is not judged merely by their size, but by their significance also. From a real knowledge of these few types and their life history it is easy to advance in school days or afterwards to a rational understanding of a great number of forms. Few students ever go so far in school as to study the forests of North America or the fauna of South America. It is sufficient for them to gain a fair acquaintance with a good number of the type forms that make up these totals. It is quite time that geography should as far as possible be studied in the same way. No school boy can gain a comprehensive idea of the structure of a continent until he knows minutely the individual parts of which continents are composed. No explorer can perceive the full meaning of the country he traverses, or record his observations so that they can be read intelligently by others until he is fully conversant with the features of geographic types and with the changes in their expression as they grow old. Both scholar and explorer should be trained in the examination and description of geographic types, not necessarily copies of actual places, before attempting to study the physical features of a country composed of a large number of geographic individuals. When thus prepared, geography will not only serve in geologic investigation, it will prosper in its proper field as well.

Geographic description will become more and more definite as the observer has more and better type forms to which he may liken those that he finds in his explorations, and the reader, taught from the same types, will gather an intelligent appreciation of the observer's meaning. Take the region north of Philadelphia above referred to. Having grown up upon it, I called it a hilly country, in accordance with the geographic lessons of my school days, and continued to do so for twenty years or more, until on opening my eyes its real form was perceived. It is a surface worn down nearly to a former base level but now diversified by ramifying valleys, cut into the old base level in consequence of a subsequent but not very ancient elevation of a moderate amount. Maturity is not yet reached in the present cycle of development, for there is still much of the old base level surface remaining, into which the valleys are gnawing their head ravines and thus increasing the topographic differentiation. Perhaps not more than a sixth of the total mass above present base level is yet consumed. To say that a country is hilly gives so wide a range to the imagination that no correct conception of it can be gained, but I venture to think that one who understands the terms used can derive a very definite and accurate conception from the statement that a certain country is an old, almost completed base level, raised from one to three hundred feet, and well advanced toward maturity in its present cycle of change.

It is from geographic methods thus conceived that geologic investigation will gain assistance. As the subject is properly developed it will form an indispensable part of the education of every explorer, topographer and geologist; and in its simpler chapters it will penetrate the schools. There is no other subject in which there is greater disproportion between the instruction, as commonly carried on, and the opportunity for application in after life. The intelligent part of the world is travelling from place to place to an extent that our fathers could not have believed possible, and yet not one person in ten thousand has any geographic instruction that enables him to see more than that a river is large or small, or that a hill is high or low. The meaning of geography is as much a sealed book to the person of ordinary intelligence and education as the meaning of a great cathedral would be to a backwoodsman, and yet no cathedral can be more suggestive of past history in its many architectural forms than is the land about us, with its innumerable and marvelously significant geographic forms. It makes one grieve to think of the opportunity for mental enjoyment that is lost because of the failure of education in this respect.

It may be asked perhaps how can one be trained in geographic types, seeing that it is impossible for schools to travel where the types occur. This is surely a great and inherent difficulty, but it may be lessened if it cannot be overcome. Good illustrations are becoming more and more common by means of dry plate photography; maps are improving in number and quality; but the most important means of teaching will be found in models. No maps, illustrations or descriptions can give as clear an idea of relief as can be obtained from a well-made model, and with a set of models, fifty or sixty in number, the more important types and their changes with age can be clearly understood. Maps, illustrations and descriptions supplement the models. The maps should be contoured, for in no other way can the quantitative values be perceived that are essential to good study. The illustrations should be of actual scenes; or, if designs, they should be designed by a geographic artist. The descriptions should wherever possible be taken from original sources, in which the narrator tells what he saw himself. It is, to be sure, not always possible to know what kind of a form he describes, owing to lack of technical terms, but many useful examples can be found that may then be referred to their proper place in the system of geographic classification that is adopted.

I shall consider only one example in detail to show how far short, as it seems to me, geography fails of its great opportunity, both as taught in schools and as applied in after life.

In northeastern Pennsylvania there are several water-falls that leap over tilted beds of rock. Such falls are known to be of rare occurrence, and we may therefore inquire into the cause of their rarity and the significance of their occurrence in the region referred to.

We may first look at the general conditions of the occurrence of water-falls. They indicate points of sharply contrasted hardness in the rocks of the stream channel, and they show that the part of the channel above the fall has not yet been cut down to base level. When the channel reaches base level there can be no falls. Now it is known from the general history of rivers that only a short part of their long lives is spent in cutting their channels down to base level, except in the case of headwater streams, which retain youthful characteristics even through the maturity of their main river. Consequently, it is not likely that at any one time, as now, in the long lives of our many rivers, we should see many of them in their short-lived youthful phase. Falls are exceptional and denote immaturity. They endure a little longer on horizontal beds, which must be cut back perhaps many miles up stream before the fall disappears, than on tilted beds, which must be cut down a few thousand feet at most to reduce them to base level. Falls on tilted beds are therefore of briefer duration than on horizontal beds, and are at any time proportionately rarer. On the headwater branches of a river where youthful features such as steep slope and sudden fall remain after the main river has a well-matured channel, we sometimes find many water-falls, as in the still young branches of the old Ohio. These are like young twigs on an old tree. But even here the rocks are horizontal, and not tilted as in the cases under consideration.

The falls of such headwater streams must persist until the plateau is cut away, for the cap rocks over which the streams leap being horizontal cannot be smoothed down till the whole plateau is cut through. They are long-lived features. Moreover every one of the innumerable branch streams must on its way down from the uplands fall over the outcropping edges of all the hard beds. The falls will therefore be common as well as long-lived features. Their frequent occurrence confirms the correctness of this generalization. On the other hand, in regions of tilted rocks, the hard beds are avoided by the streams, which select the softer strata for their valleys. The hard beds soon stand up as ridges or divides, across which only the large streams can maintain their courses, and these are the very ones that soon cut down any fall that may appear in their early stages. Falls on tilted rocks are therefore rare not only because of their brief duration, but also because tilted rocks are crossed by few streams, except the large ones, which soon cut away their falls.

The foregoing considerations show clearly enough that falls like those of northeastern Pennsylvania are rare, and we have now to consider why they should be prevalent in the region in question. The Appalachians contain many water-gaps cut down on tilted beds, every one of which may have been the site of a fall for a relatively brief period of river immaturity, but this brief period is now left far in the past. The streams show many signs of maturity: their slope is gentle and their valleys are wide open from Alabama to Pennsylvania, but in the northeastern corner of the latter State we find a group of streams that leap over high benches into narrow gorges, and the benches are held up by tilted rocks. Manifestly the streams have in some way been lately rejuvenated; they have been, in part of their courses at least, thrown back into a condition of immaturity, at a time not long past, and, as has so well been shown by White, the cause of this is the obstruction of their old channels by irregular deposits of glacial drift. Here first in the whole length of the Allegheny section of the Appalachians we find an exceptional condition of stream life, and here also we come into a region lately glaciated, where heaps of drift have thrown the streams out of their old tracks. The explanation fits perfectly, and if it had not been discovered by inductive observation in the field, the need of it might have been demonstrated deductively. It is a case that has given me much satisfaction from the promise that it holds out of a wide usefulness for geography, when its forms are systematically studied and its principles are broadly applied.

A final word as to terminology. The material common to geography and geology may be included under the name physiography, as used by Huxley. It is, I think, a subject that is destined to receive much attention. Physical geography, as ordinarily defined, does not cover the ground that it might fairly claim. It is too largely descriptive and statistical. Geographic evolution, as defined by Geikie, is the general preparation of existing geography by geologic processes. It does not consider the general scheme of topographic development or the natural classification of geographic forms.

It is not easy to change the accepted meaning of a term, and I would therefore suggest that a new term should be introduced to include the classification of geographic forms, as advocated here, rather than that any old and accepted term should be stretched over a new meaning. As the essential of the study here outlined is the systematic relation of form to structure, base level and time, the new term might be Systematic Geography.

THE CLASSIFICATION OF GEOGRAPHIC FORMS BY GENESIS.

By W. J. McGee.

Scientific progress may be measured by advance in the classification of phenomena. The primitive classification is based on external appearances, and is a classification by analogies ; a higher classification is based on internal as well as external characters, and is a classification by homologies ; but the ultimate classification expresses the relations of the phenomena classified to all other known phenomena, and is commonly a classification by genesis.

The early geologic classification was based chiefly upon simple facts of observation ; but with continued research it is found that the processes by which the phenomena were produced may be inferred, and, accordingly, that the phenomena may be grouped as well by the agencies they represent as by their own characteristics. Thus the empiric or formal laws of relation give place to philosophic or physical laws indicating the casual relations of the phenomena, and the final arrangement becomes genetic, or a classification by processes rather than products.

The phenomena of geography and geology are identical, save that the latter science includes the larger series : since the days of Lyell the geologist has seen in the existing conditions and agencies of the earth a reflection and expression of the conditions under which and the agencies by which its development has been effected ; the far stretching vista of geologic history is illuminated only by knowledge of the earth of to-day ; and the stages in geologic development are best interpreted in terms of geography. So a genetic classification of geologic phenomena (which is rendered possible and intelligible through geographic research) will apply equally to geography, whether observational or of the more philosophic nature which Davis proposes to call Systematic Geography, and which Powell has called Geomorphology. Such a classification is here outlined.

The various processes or movements with which the geologist has to deal fall naturally into two principal and antagonistic categories and five subordinate categories ; and each category, great and small, comprises two classes of antagonistic processes or movements.

The initial geologic movements (so far as may be inferred from the present condition of the earth) were distortions or displacements of the solid or solidifying terrestrial crust, occurring in such manner as to produce irregularities of surface. These are the movements involved in mountain growth and in the upheavel of continents. They have been in operation from the earliest known eons to the present time, and their tendency is ever to deform the geoid and produce irregularity of the terrestrial surface. The movements have been called collectively "displacement" and "diastrophism," but in the present connection they may be classed as *diastatic*, or, in the substantive form, as *deformation*. Recent researches, mainly in this country, have indicated that certain diastatic movements are the result of transference of sediment — that areas of loading sink, and areas of unloading rise; but it is evident that the transference of sediment is itself due to antecedent diastatic movements by which the loaded areas were depressed and the unloaded areas elevated; and the entire category may accordingly be divided into *antecedent* and *consequent* diastatic movements. A partially coincident division may be made into *epeirogenic*, or continent-making movements (so called by Gilbert), and *orogenic*, or mountain-making movements. Though there is commonly and perhaps always a horizontal component in diastatic movement, the more easily measured component is vertical, and when referred to a fixed datum (*e. g.* sea level) it is represented by *elevation* and *depression*.

The second great category of geologic processes comprehends the erosion and deposition inaugurated by the initial deformation of the terrestrial surface. By these processes continents and mountains are degraded, and adjacent oceans and lakes lined with their debris. They have been in active operation since the dawn of geologic time, and the processes individually and combined ever tend to restore the geoid by obliterating the relief produced by deformation. The general process, which comprises *degradation* and *deposition*, may be called *gradation*.

The first subordinate category of movements is allied to the first principal category, and comprises, (1) the outflows of lavas, the formation of dykes, the extravasation of mineral substances in solution, etc., (2) the consequent particle and mass movements within the crust of the earth, and (3) the infiltration of minerals in solution, sublimation, etc.,— in short, the modification of the earth's exterior directly and indirectly through particle movements induced by the condition of the interior. These processes have been in operation throughout geologic time, though they perhaps represent a diminishing series; they have added materially to the superficial crust of the earth; and it is fair to suppose that they have modified the geoid not only by additions to the surface but by corresponding displacements in their vicinity. The category may be tentatively (but rather improperly) called *vulcanism*, and the antagonistic classes of movements constituting it are *extravasation* and its antithesis. The vibratory movements of *seismism* probably result from both deformation and vulcanism under certain conditions.

The second subordinate category of processes is closely linked with all of the others. It comprises the various chemic and chemico-mechanical alterations in constitution and structure of the materials of the earth's crust. The processes have affected the rocks ever since the solidification of the planet, though probably in a progressively diminishing degree; and they have materially (but indirectly rather than directly) modified the internal constitution and external configuration of the earth. The processes may be collectively called *alteration;* and the antagonistic classes into which the category is divisible are *lithifaction* and *decomposition* in their various phases, or *rock-formation* and *rock-destruction.*

The third subordinate category of processes, viz: *glaciation*, is related to the second principal category; but since (1) it is probable if not actually demonstrable that under certain circumstances glacial grinding tends to accentuate preëxisting irregularities of surface, and since (2) it is well known that glacial deposition sometimes gives great irregularity of surface, it is evident that glaciation is not a simple process of gradation, but must be clearly distinguished therefrom. A considerable portion of the earth's surface has been modified by glaciation during later geologic times. The general process comprises *glacial construction* and *glacial destruction.*

There is a fourth subordinate category of processes, which is also allied to gradation, viz: *wind-action*, which may be made to include the action of waves and wind-born currents; but since the winds scoop out basins and heap up dunes, while the waves excavate submerged purgatories and build bars, it is evident that this category, too, must be set apart. The processes are only locally important as modifiers of the land surface of the globe. They comprise constructive action and destructive action.

There is a final category which is in part allied to alteration but is in part unique, viz: the chemic, mechanical, and dynamic action of organic life. Ever since the terrestrial crust become so stable as to retain a definite record of the stages of world-growth, life has existed and by its traces has furnished the accepted geologic chronology: at first the organisms were simple and lowly, and affected the rocks chemically through their processes of growth and decay, as do the lower plants and animals of the present; later, certain organisms contributed largely of their own bodily substance to the growing strata; and still later, the highest organisms, with man at their head, have by dynamic action interfered directly with gradation, alteration, and wind-action, and thus, perhaps, indirectly with the more deep-seated processes of world growth. The vital forces are too varied in operation to be conveniently grouped and named.

These categories comprise the various processes contemplated by the geologist, and collectively afford an adequate basis for a genetic classification of geologic science. Their relations are shown in the accompanying table:

Classification of Geologic Processes.

Principal Categories	1.—Deformation.	Antecedent<Epeirogenic Consequent>Orogenic.	Elevation. Depression.
	2.—Gradation.		Deposition. Degradation.
Subordinate Categories.	1.—Vulcanism.		Extravasation. (Antithesis of Extrav.)
	2.—Alteration.		Lithifaction. Decomposition.
	3.—Glaciation.		Glacial construction. Glacial destruction.
	4.—Wind action.		Wind construction. Wind destruction.
	5.—Vital action.		Various constructive and destructive processes.

On applying this classification to geographic forms, the various phenomena immediately fall into the same arrangement. The continents, great islands, mountain systems, and non-volcanic ranges and peaks generally, the oceans, seas, and some bays, gulfs and lakes, evidently represent the diastatic category of movements. These greater geographic features have long been named and classified empirically, and can be referred to their proper places in a genetic taxonomy without change in terminology. The volcanoes, craters, calderas, lava fields, tuff fields, tufa crags, mesas, volcanic necks, dykes, etc., however modified by degradation, alteration, glaciation, or wind action, exhibit characteristic forms which have often received names indicative of their origin. The glacial drift with its various types of surface, the moraines, drumlins, kames, roches de moutonnées, rock basins, kettles, lacustral plains, aqueo-glacial terraces, loess hills and plains, etc., have been studied in their morphologic as well as their structural aspects, and the elements of the configuration commonly assumed have been described, portrayed, and appropriately named; and they take a natural place in the classification of products by the processes giving rise to them. The dunes, dust drifts, sand ridges, etc., and the wind-scooped basins with which they are associated, are local and limited, but are fairly well known and fall at once into the genetic classification of forms and structures. But all of these geographic forms are modified, even obliterated, by the ever prevailing process of gradation, which has given origin to nearly all of the minor and many of the major geographic forms of the earth. The forms resulting from this second great category of geologic processes have generally engaged the attention of systematic students, but their prevalence, variety and complexity of relation are such that even yet they stand in greatest need of classification.

Lesley thirty years ago regarded the mountain as the fundamental topographic element; Richthofen recognizes the upland and the plain ("aufragendes Land und Flachböden") as the primary classes of configuration comprehending all minor elements of topography; Dana groups topographic forms as (1) lowlands, (2) plateaus and elevated table lands, and (3) mountains; and these related allocations are satisfactory for the purposes for which they are employed. But the implied classification in all these cases is morphologic rather than genetic, and is based upon superficial and ever varying if not fortuitous characters; and if it were extended to the endless variety of forms exhibited in the topography of different regions it would only lead to the discrimination of a meaningless multitude of unrelated topographic elements.

In an exceedingly simple classification of geographic phenomena, the primary grouping is into *forms of construction* and *forms of destruction;* but it is evident on inspection of the table introduced above that such a classification is objectionable unless the greater geographic elements due to diastatic movements (in which the constructive action is veritable but different in kind from those in the other categories) be excluded, and this is impracticable without limiting the classification to subordinate phenomena. Moreover it is illogical and useless to unite the constructive phenomena of the remaining categories, since (1) the processes exemplify widely diverse laws, which must find expression in any detailed classification whether genetic or not, and since (2) the differences between the forms united are much greater than the differences between the forms separated in such a classification — e. g. the differences between a dune, a drumlin and a mesa (all constructive forms) are far greater than the differences between a fresh lava sheet and a deeply cut mesa, between a drumlin and the smallest drift remnant, or between a dune and a Triassic mound of circumdenudation; and this is true whether the distinction be made on analogic, homologic, or genetic grounds. Indeed it seems evident that while discrimination of constructive and destructive forms is necessary and useful in each genetic category, the use of this distinction as a primary basis of classification is inexpedient.

The classification of topographic forms proposed a few years ago by Davis, who regards "special peculiarities of original structure" as a primary, and "degree of development by erosion" a secondary basis, and Richthofen's arrangement of categories of surface forms as (1) tectonic mountains, (2) mountains of abrasion, (3) eruptive mountains, (4) mountains of deposition, (5) plains, and (6) mountains of erosion,* in addition to depressions of the land (Die Hohlformen des Festlandes), are more acceptable, since they are based in part on conditions of genesis. But it is clearly recognized by modern students of dynamic geology that waterways are the most persistent features of the terrestrial surface; and the most widely applicable systems of classification of the surface configuration of the earth thus far proposed have been based substantially on the agencies of gradation. Thus Powell, Löwl and Richthofen classify valleys by the conditions of their genesis; Gilbert classifies drainage; and Phillipson, unduly magnifies the stability and genetic importance of the water parting, classifies the hydrography through

* (1) Tektonische Gebirge, (2) Rumpfgebirge oder Abrasionsgebirge, (3) Ausbruchsgebirge, (4) Aufschüttungsgebirge, (5) Flachböden, und (6) Erosionsgebirge.

the divides; and, although these geologists have not dwelt upon and perhaps have failed to perceive the relation, the same classification is as applicable to every feature of the local relief as to the streams by which the relief was developed.

In a general classification of the topographic forms developed through gradation, it would be necessary to include the forms resulting from deposition as well as degradation, and also to discuss the relation of base-level plains to antecedent and consequent relief; but in a brief résumé it will suffice to consider only the modifications produced by degradation upon a surface of deposition after its emergence from beneath water level as a regular or irregular terrane; and the influence of base-level upon the topographic forms developed upon such a surface may be neglected in a qualitative discussion, though it is quite essential in quantitative investigation.

The hydrography developed upon terranes affected by displacement both before and after emergence has already been satisfactorily classified. Powell, years ago, denominated valleys established previous to displacement of the terrane by faulting or folding, *antecedent* valleys; valleys having directions depending on displacement, *consequent* valleys; and valleys originally established upon superior and subsequently transferred to inferior terranes, *superimposed* valleys; and these valleys were separated into orders determined by relation to strike and again into varieties determined by relation to subordinate attitude of the terranes traversed. Gilbert adopted the same general classification, and so extended as to include certain special genetic conditions. Tietze, in the course of his investigation of the Sefidrud (or Kizil Uzen) and other rivers in the Alburs mountains of Persia, independently ascertained the characteristics of the class of waterways comprehended by Powell under the term antecedent; Medlicott and Blanford observed that many of the Himalayan rivers are of like genesis; and Rütimeyer, Peschel and others have recognized the same genetic class of waterways; but none of these foreign geologists have discussed their taxonomic relations. Löwl, who upon *a priori* grounds denies the possibility of antecedent drainage, has recently developed an elaborate taxonomy of valleys which he groups as (*a*) tectonic valleys, and (*b*) valleys of erosion (Erosionsthäler). The first of these categories is separated into two classes, viz: valleys of flexure and valleys of fracture, and these in turn into several sub-classes determined by character of the displacement and its relations to structure; and the second, whose genesis is attributed to retrogressive (rückwärts fortschreitende" or "rückschreitende") erosion, is vaguely separated into several ill-defined classes and sub-classes determined by structure, climate, and various other conditions. The second of Löwl's categories is also recognized by Phillipson. Still more recently, Richthofen, neglecting antecedent drainage, designated the superimposed class of Powell *epigenetic*, and formulated a classification of the remaining types of continental depressions (Die Hohlformen des Festlandes) as (*a*) orographic depressions (Landsenken); (*b*) tectonic valleys, and (*c*) sculptured valleys; and the last two categories are separated into classes and sub-classes, corresponding fairly with those of Löwl, determined by their relations to structure and by various genetic conditions.

These several classifications have much in common; their differences are largely due to the diversity of the regions in which the investigations of their respective authors have been prosecuted; but combined they probably comprehend all the topographic types which it is necessary to discriminate.

The American classification and nomenclature, particularly, is unobjectionable as applied to montanic hydrography; but it does not apply to the perhaps equally extensive drainage systems and the resulting topographic configuration developed on emergent terranes either (*a*) without localized displacement or (*b*) with localized displacement of less value in determining hydrography than the concomitant erosion, terracing and reef building; neither does it apply to the minor hydrography in those regions in which the main hydrography is either antecedent or consequent; nor does it apply even to the original condition of the superimposed or antecedent drainage of montainous regions.

Upon terranes emerging without displacement and upon equal surfaces not yet invaded by valleys, the streams depend for their origin on the convergence of the waters falling upon the uneroded surface and affected by its minor inequalities, and for their direction upon the inclination of that surface. They are developed proximally (or seaward) by simple extension of their courses by continued elevation, and distally by the recession of the old and the birth of new ravines; and since in the simple case it follows from the law of probabilities that the receding ravine will retain approximately the old direction and that the new ravines will depart therefrom at high angles, the drainage systems thus independently developed become intricately but systematically ramified and more or less dendritic in form. Löwl, Phillipson, Richthofen, and other continental, as well as different British and Indian geologists, and Lesley in this country, indeed recognize this type of drainage, but they do not correlate it with the montanic types; and Löwl's designation, derived from the manner in which he conceives it to be generated ("rückschreitende Erosion"), does not apply to either the completed drainage or the coincident topography.

Although its subordinate phases are not yet discriminated on a genetic basis, this type or order of drainage is sufficiently distinct and important to be regarded as coördinate with the type represented by the entire group of categories recognized by Powell and clearly defined by Gilbert. Such hydrography (which either in its natural condition or superimposed characterizes many plains, some plateaus, and the sides of large valleys of whatever genesis) may be termed *autogenous*; while the drainage systems imposed by conditions resulting from displacement (which characterize most mountainous regions) may be termed *tectonic*. Gilbert's classification of drainage may then be so extended as to include topography as well as hydrography, and so amplified as to include the additional type.

Drainage systems and the resulting systems of topography (all of which belong to the degradational class of forms) are accordingly.—

Type 1, Autogenous.
Type 2, Tectonic—
- Order A, Consequent, upon
  - Class *a*, Displacement before emergence, and
  - Class *b*, Sudden displacement after emergence;
- Order B, Antecedent; and
- Order C, Superimposed, through
  - Class *a*, Sedimentation (when the superimposed drainage may be autogenous),
  - Class *b*, Alluviation or subaerial deposition, and
  - Class *c*, Planation (in which two cases the superimposed drainage may simulate the autogenous type).

In brief, the entire domain of geologic science is traversed and defined by a genetic classification of the phenomena with which the geologist has to deal; and the same classification is equally applicable to geographic forms, as the accompanying table illustrates:

Representative Geographic Forms as classified by Genesis.

Genetic Processes. Category.	Class.	Geographic Forms.
Deformation	Elevation	Continents, great islands, most mountain ranges, etc., not classified in detail.
	Depression	Oceans, great seas and bays, some inland valleys and lake-basins, etc., not classified in detail.
Gradation	Deposition	Newly emerged ocean-bottoms (*e. g.*, portions of the Coastal plain), playas and mountain-bound deserts, many flood-plains, marshes, etc., not classified in detail.
	Degradation	Drainage-systems and resulting topographic elements which are— 1—Autogenous (not classified in detail); and 2—Tectonic— Consequent, upon Displacement before emergence, and Sudden displacement after emergence; Antecedent; and Superimposed, through Sedimentation, Alluviation, and Planation.
Vulcanism	Extravasation	Volcanic peaks, craters, lava-fields, tufa-crags, sinter-cones, volcanic necks, mesas, dykes, some mineral veins, etc., not classified in detail.
	(Antithesis of do.)	Sinks, caverns, some fissures, etc., not classified in detail.
Alteration	Lithifaction	Minor features of certain topographic forms, *e. g.*, reefs, crags, pinnacles, salients, out-cropping veins, some cataracts, etc., not classified in detail.
	Delithifaction	Minor features of certain topographic forms, *e. g.*, pools and basins, reëntrants, some fissures and caverns, etc., not classified in detail.
Glaciation	Glacial construction	Drift-plains, moraines of whatever character, drumlins, kames, aasar, drift-dammed lakes, loss-plains and ridges, etc., not classified in detail.
	Glacial destruction	Rock-basins, U-cañons, roches de moutonnées, etc., not here classified in detail.
Wind Action	Wind construction	Dunes, sand-ridges, bars, spits, etc., not here classified in detail.
	Wind destruction	Ponds associated with dunes, "blow-outs," "purgatories," etc., not classified in detail.
Vital Action	(Not discriminated)	

THE GREAT STORM OF MARCH 11–14, 1888.

A SUMMARY OF THE REMARKS MADE BY BRIGADIER-GENERAL A. W. GREELY, CHIEF SIGNAL OFFICER OF THE ARMY.

THIS storm is by no means as violent as others which have occurred in the eastern part of the United States. It is noted, however, as being one in which an unusual amount of snow fell, which, drifted by the high winds caused by the advance of an anticyclonic area in rear of the storm depression, did an enormous amount of damage to the railways in Massachusetts, southern New York, and New Jersey.

The storm centre was first noticed in the North Pacific on March 6th; whence it passed southeast from the Oregon coast to northern Texas by the 9th. The centre instead of maintaining the usual elliptical form, gradually shaped itself into an extended trough of low pressure, which covered the Mississippi and Ohio valleys during the 10th. On the morning of March 11th the barometer trough extended from Lake Superior southward to the eastern part of the Gulf of Mexico; in the northern section over Lake Superior, and the southern part, over Georgia, distinct centres, with independent wind circulation, had formed.

The northern storm centre moved northeastward and disappeared, while the southern centre moved slowly eastward, passing off the Atlantic coast near Cape Hatteras. The pressure on the afternoon of March 11th was about 29.07 at the centre of both the northern and southern storms, but during the night of the 11–12th the pressure decreased in the southern storm centre, and the area instead of continuing its easterly direction moved almost directly to the north, and on the morning of March 12th was central off the New Jersey coast.

The causes which underlie the decrease of pressure and consequent increase in the violence of storms are, as yet, undetermined. The theory of "surges," that is, atmospheric waves independent of the irregular variations consequent on storms, has been urged by some, and especially by Abercromby, as the cause of the deepening of depressions in some cases or of increasing the pressure in other cases. It is possible that under this theory a "surge," passing over the United States to the eastward, as its trough became coincident with the centre of low pressure increased its intensity or decreased its pressure, and the consequent increase in barometric gradients added to the violence of the winds. It should be pointed out, however, that the very heavy rainfalls from Philadelphia southward to Wilmington during the 11th, and even the heavier ones over the lower valley of the Hudson and in Connecticut during the 12th, may have exercised a potent influence in depressing the barometer at the centre of this storm. However this may be, it is certain that the storm remained nearly stationary, with steadily decreasing pressure until midnight of March 12th, at which time it was central between Block Island and Wood's Holl, with an unusually low barometer of 28.92 at each station. During this day the winds were unusually high along the Atlantic coast from Eastport to Norfolk; the maximum velocities at the various stations ranging from 48 miles at New York City and New Haven to 60 miles at Atlantic City and 70 miles per hour at Block Island. These winds, though high, are not unprecedented, and if they had been accompanied only by precipitation in the form of rain, the damage on land would have been inconsiderable, but, unfortunately for the commercial interests of New York and other neighboring great cities, the passage of the low area to the eastward was followed by a cold wave of considerable severity and of unusual continuance.

The northern storm centre, which had passed eastward on the 11th, had had the usual effect of drawing in a large quantity of cold air from British America; a cold wave following the wake of this storm, as is usual during the winter season. This usual effect was intensified by the advance of a second, and more violent, cyclonic centre northward; the effect of which was to augment the cold wave already in progress by drawing in a still larger amount of cold air to re-enforce it.

As has been already alluded to, the quantity of snowfall was unusually great. The easterly and northeasterly winds had drawn a large amount of aqueous vapor from the Atlantic over New England in advance of the low area. The sudden change of temperature precipitated by far the greater portion of the aqueous vapor in the air, with the result of an almost unprecedented fall of snow over western Massachusetts, Connecticut, and the valley of the Hudson.

Professor Winslow Upton, Secretary of the New England Meteorological Society, has gathered estimates of snow from 420 different observers, which go to show that 40 inches or more of snow fell over the greater part of the districts named.

The deepening of the area of low pressure and the augmentation of the cold high area advancing from British America resulted in barometric gradients of unusual intensity; there being gradients in excess of 6, when gradients of 5 rarely occur either in the United States or Great Britain. The high winds caused by these unusual gradients had the effect of drifting the snow to an unusual extent, so that, as is well known, nearly every railroad in New Jersey, Connecticut, New York, and Massachusetts was snow-bound; the earliest and most prolonged effects being experienced in Connecticut, which doubtless received the full benefit of the heavy snowfall in the Hudson River valley in addition to that in the western part of that State.

It is thought by some that the storm re-curved and passed northwest into Connecticut; an opinion in which I cannot concur. The international map and reports tend to show that this storm passed northeastward and was on the Banks of Nowfoundland on the 17th of March. The peculiar shape of the isobars, while the storm could be clearly defined from observations at hand, was such that it is not unreasonable to believe that the change of wind to the south at Block Island was due simply to an off-shoot of the storm from the main centre, in like manner as the storm itself was the outgrowth of a previous depression.

The track of this storm across the sea is left to Professor Hayden. These remarks are necessarily imperfect, as my official duties have been such as to prevent any careful study or examination of the storm apart from that possible on the current weather maps of the Signal Service.

THE GREAT STORM OFF THE ATLANTIC COAST OF THE UNITED STATES, MARCH 11TH–14TH, 1888.

By Everett Hayden,
In charge of the division of Marine Meteorology, Hydrographic Office, Navy Dept.

Introduction.

The history of a great ocean storm cannot be written with any completeness until a long interval of time has elapsed, when the meteorological observations taken on board hundreds of vessels of every nationality, scattered over the broad expanse of ocean, and bound, many of them, for far distant ports, can be gathered together, compared, and, where observations seem discordant, rigidly analyzed and the best data selected. It is only when based upon such a foundation that the story can fully deserve the title of history, and not romance, fact and not hypothesis. At best, there must be wide areas where the absence of vessels will forever leave some blank pages in this history, while elsewhere, along the great highways of ocean traffic, the data are absolutely complete. Last August a tropical hurricane of terrific violence swept in toward our coast from between Bermuda and the Bahamas, curved to the northward off Hatteras, and continued its destructive course past the Grand Banks toward northern Europe; hundreds of reports from masters of vessels enabled us accurately to plot its track, a great parabolic curve tangent to St. Thomas, Hatteras, Cape Race, and the northern coast of Norway. Six months later a report forwarded by the British Meteorogical Office, from a vessel homeward bound from the Equator, indicated that it originated far to the eastward, off the coast of Africa, and only the other day the log of a ship which arrived at New York, March 30th, from Calcutta, supplied data by means of which the storm track can be traced still more accurately, westward of the Cape Verde islands. Not only that, but this same vessel on the 11th of March was about 500 miles to the eastward of Bermuda, and, while the great storm was raging between Hatteras and Sandy Hook, was traversing a region to the northeastward of Bermuda from which our records are as yet very incomplete. It will thus be clearly understood that while the most earnest efforts have been made, not only to collect and utilize all available information, but to be careful and cautious in generalizing from the data at hand, yet this study must be considered as only preliminary to an exhaustive treatise based on more complete data than it is now possible to obtain.

Four charts have been prepared to illustrate the meteorological conditions within the area from 25° to 50° north latitude, 50° to 85° west longitude, at 7 A. M., 75th meridian time, March 11th, 12th, 13th and 14th respectively. Data for land stations have been taken from the daily weather maps published by the U. S. Signal Service, and the set of tri-daily maps covering the period of the great storm has been invaluable for reference throughout this discussion. Marine data are from reports of marine meteorology made to this office by masters of vessels, and not only from vessels within the area charted, but from many others just beyond its limits. The refined and accurate observations taken with standard instruments at the same moment of absolute time all over the United States by the skilled observers of the Signal Service, together with those contributed to the Hydrographic Office by the voluntary co-operation of masters of vessels of every nationality, and taken with instruments compared with standards at the Branch Hydrographic Offices immediately upon arrival in port, make it safe to say that never have the data been so complete and reliable for such a discussion at such an early date.

It will not be out of place briefly to refer to certain principles of meteorology that are essential to a clear understanding of what follows. The general atmospheric movement in these latitudes is from west to east, and by far the greater proportion of all the areas of low barometer, or centers of more or less perfectly developed wind systems, that traverse the United States, move along paths which cross the Great Lakes, and thence reach out over the Gulf of St. Lawrence across the Atlantic toward Iceland and northern Europe. Another very characteristic storm path may also be referred to in this connection, the curved track along which West Indian hurricanes travel up the coast. The atmospheric movement in the tropics is, generally speaking, westward, but a hurricane starting on a westward track soon curves off to the northwest and north, and then getting into the general eastward trend of the temperate zone, falls into line and moves off to the northeast, circling about the western limits of the area of high barometer which so persistently overhangs the Azores and a great elliptical area to the southwestward. The circulation of the wind about these areas of low barometer, and the corresponding changes of temperature, are indicated graphically on the map: the isobars, or lines of equal barometric pressure, are, as a rule, somewhat circular in form, and the winds blow about and away from an area of "high" in a direction *with the hands of a watch* (in nautical parlance, "with the sun"), toward and about "low" with an opposite rotary motion, or against the hands of a watch; in front of a "low" there will therefore be, in extra tropical latitudes, warm southeasterly winds, and behind it cold northwesterly winds, the resulting changes of temperature being shown by the isotherms, or lines of equal temperature. Moreover, in a cyclonic system of this kind the westerly winds are generally far stronger than the easterly winds, the motion of the whole system from west to east increasing the apparent force of the former and decreasing that of the latter. Upon reaching the coast, such areas of low barometer, or storm systems, almost invariably develop a great increase of energy, largely due to the moisture in the atmosphere overhanging the ocean, which, when the air is chilled by contact with the cold dry air rushing in from the "high," is precipitated and becomes visible in the form of clouds, with rain or snow. The latent heat liberated by the condensation of this aqueous vapor plays a most important part in the continuance of the storm's energy and, indeed, in its increase of energy: the warm light air flowing in towards the central area of the storm rises rapidly into regions where the pressure is less, that is, where the thickness and consequently the weight of the superincumbent atmosphere is less; it therefore rapidly expands, and such expansion would result in a much more rapid cooling, and a corresponding decrease in its tendency to rise still higher, were it not for the latent heat liberated by the condensation of the moisture which it contains. Thus the forces that are conspiring to increase the energy of the storm are powerfully assisted by the presence and condensation of aqueous vapor, and the increasing updraught and rarefaction are at once marked by the decreasing barometric pressure at the center. For example, a storm was central over the Great Lakes on Jan. 25th, with lowest barometer 29.7; the following day it was central off Nantucket, barometer 29.2; and on the 27th and 28th, over the Gulf of St. Lawrence, with barometer below 28.6. But such instances are so common as to make it the rule, and not the exception.

As stated above, the isobars about an area of low barometer are somewhat circular in form; more strictly speaking, they are somewhat oval or elliptical in shape, and the more elongated the north and south axis of this ellipse, the greater the resulting changes of temperature, because, as it moves along its broad path toward the Atlantic, the indraught, or suction, is felt in front far down toward the tropics, and in rear far to the northward, beyond the territorial limits of the United States.

Similarly with regard to the general movement of areas of high barometer, certain laws of motion have been clearly established by means of studies of the daily international charts; instead of a motion toward east-northeast, these areas when north of the 40th parallel, have in general a motion towards east-southeast, and as a rule move more rapidly and with greater momentum than "lows," so that they may be said to have the right of way, when the tracks of two such systems converge or intersect. These laws, or at least that relating to the Great Lake storm track, as it may be called, soon become evident to anyone who watches the weather map from day to day, upon which are charted the systems of low and high barometer as they follow one another across the continent, bringing each its characteristic weather.

March 11th, 7 A. M.

The first of the accompanying weather charts indicates graphically the meteorological conditions over the wide area charted, comprising about 3,000,000 square miles, of which one-third is land and two-thirds water. Over the land there is a long line, or trough, of low barometer, extending from the west coast of Florida up past the eastern shore of Lake Huron, and far northward toward the southern limits of Hudson Bay. In front of this advancing line the prevailing winds are southeasterly, and the warm moist air drawn up from southern latitudes spreads a warm wave along the coast, with generally cloudy weather and heavy rains, especially south of Hatteras; the Signal Service observer at Pensacola, for example, reports the heavy rain-fall of 4.05 inches on the 10th. About midway of this trough of low barometer there is a long narrow region of light variable winds; of rapid changes in meteorological conditions; calms, shifts of wind, intervals of clearing weather; then overcast again, with cooler and fresh northwesterly winds, increasing to a gale. The front line of this advancing battalion of cold northwesterly winds is more than a thousand miles in length, and covers the whole breadth of the United States: its right flank is on the Gulf, its left rests on the Great Lakes, or even farther north; the temperature falls rapidly at its approach, with frost far south into Louisiana and Mississippi, and heavy snow in central Kentucky and eastern Tennessee. The long swaying line is advancing toward the coast at the rate of about 600 miles a day, followed by a ridge of high barometer reaching from Texas to Dakota and Manitoba. At points along the trough the barometer ranges from 29.70, a hundred miles north of Toronto, to 29.86 at Pittsburg, 29.88 at Augusta, and 29.94 at Cedar Keys. Along the ridge the barometer is very high; 30.7 to the northward about Lake Winnipeg, 30.6 in Wyoming, 30 7 in Indian Territory, and 30.5 south of the Rio Grande. The difference of pressure from trough to ridge is thus measured by about an inch of mercury in the barometer. Moreover, the chart shows that there is another ridge of high barometer in advance, curving down off the coast from northern Newfoundland, where the pressure is 30.6, toward Santo Domingo, where the pressure is 30.3, and passing midway between Hatteras and Bermuda. Farther to the eastward the concentric isobars show the presence of a storm which originated about Bermuda on the 9th, and is moving off toward Europe where, in a few days, it may cause northwesterly gales with snow to the northward of its track, and southeasterly gales with rain to the southward. Storm reports from various vessels show that this storm was of hurricane violence, with heavy squalls and high seas, but it need not be referred to in this connection further than to say that it sent back a long rolling swell from northeast, felt all along the Alantic sea-board the morning of the 11th, and quite distinct from that caused by the freshening gale from the southeast.

Meteorological Conditions Off the Coast.

While this trough of low barometer, with all its attendant phenomena, is advancing rapidly eastward toward the Atlantic, and the cold wave in its train is spreading over towns, counties aud states—crossing the Great Lakes, moving up the Ohio valley, and extending far south over the Gulf of Mexico—we may pause for a moment to consider a factor which is to play a most important part in the warfare of the elements so soon to rage with destructive violence between Hatteras and Block Island, and finally to disturb the weather of the entire North Atlantic north of the 20th parallel.

The great warm ocean current called the Gulf Stream has, to most people, a more or less vague, mythical existence. The words sound familiar, but the thing itself is only an abstract idea; it lacks reality, for want of any personal experience or knowledge of its characteristic effects. To the navigator of the North Atlantic it is a reality; it has a concrete, definite existence; it is an element which enters into the calculations of his every-day life—sometimes as a friend, to help him on his course, sometimes as an enemy, to endanger, harass, and delay. Briefly, the warm waters of the tropics are carried slowly and steadily westward by the broad equatorial drift-current, and banked up in the Caribbean Sea and Gulf of Mexico, there to constitute the head or source of the Gulf Stream, by which the greater portion is drained off through the straits of Florida in a comparatively narrow and swiftly moving stream. This great movement goes on unceasingly, subject, however, to certain variations which the changing seasons bring with them. As the sun advances northward in the spring, the southeast trades creep up toward and across the equator, the volume of that portion of the equatorial current which is diverted to the northward of Cape San Roque is gradually increased, and this increase is soon felt far to the westward, in the Yucatan and Florida straits. Figures fail utterly to give even an approximate idea of the amount of heat thus conveyed from the tropics to the north temperate zone by the ceaseless pulsations of this mighty engine of oceanic circulation. To put it in some tangible shape for the mind to grasp, however, suppose we consider the amount of energy, in the form of heat, that would be liberated were this great volume of water reduced in temperature to the freezing point. Suppose, again, that we convert the number of heat-units thus obtained into units of work, so many foot-pounds, and thence ascertain the corresponding horse-power, in order to compare it with something with which we are familiar. Considering only the portion of the Gulf Stream that flows between Cape Florida and the Great Bahama bank, we find from the latest and most reliable data, collected by the U. S. Coast and Geodetic Survey, that the area of cross section is 10.97 square miles (geographic or sea miles, of 6,086 feet each); mean velocity, at this time of the year, 1.305 miles per hour; mean temperature, 71° F. These figures for mean velocity and temperature from surface to bottom are, it will be noticed, far below those for the surface current alone, where the velocity is often as great as five knots an hour, and the temperature as high as 80°. The indicated horse-power of a great ocean steamship—"La Bourgogne," "Werra," "Umbria" and "City of New York," for example—is from 9,000 to 16,000; that of some modern vessels of war is still greater; the "Vulcan," now building for the British Government, is 20,000, and the "Sardegna," for the Italian Government, 22,800. Again, if we convert into its equivalent horse-power the potential energy of the 270,000 cubic feet of water per second that rush down the rapids of Niagara and make their headlong plunge of 160 feet over the American and Horse-shoe falls, we get the enormous sum of 5,847,000. The Gulf Stream, however, is every hour carrying north through the straits of Florida fourteen and three-tenths cubic miles of water (more than three thousand times the the volume of Niagara), equivalent, considering the amount of heat it contains from 71° to 32° F., to *three trillion and sixty three billion* horse-power, or more than five hundred thousand times as much as all of these combined; indeed, considering only the amount of heat from 71° to 50°, it is still two hundred and seventy-five thousand times as great.

Sweeping northward toward Hatteras with its widening torrent, its volume still further increased by new supplies drawn in from the Bahamas and the northern coast of Cuba, its color a liquid ultramarine like the dark blue of the Mediterranean, or of some deep mountain lake, it then spreads northeastward toward the Grand banks of Newfoundland, and with decreasing velocity and lower temperature gradually merges into the general easterly drift that sets toward the shores of Europe about the 40th parallel.

The cold inshore current must also be considered, because it is to great contrasts of temperature that the violence of storms is very largely due. East of Newfoundland the Labrador current flows southward, and during the spring and summer months carries gigantic icebergs and masses of field-ice into the tracks of transatlantic steamships. Upon meeting the Gulf Stream, a portion of this cold current underruns it, and continues on its course at the bottom of the sea; another portion is deflected to the southwest, and flows, counter to the Gulf Stream, along the coast as far south as Hatteras.

The broad features of these great ocean currents have thus been briefly outlined, and, although they are subject to considerable variation as to temperature, velocity, and limits, in response to the varying forces that act upon them, this general view must suffice for the present purpose.

Now to consider for a moment some of the phenomena resulting from the presence and relative positions of these ocean currents, so far as such phenomena bear upon the great storm now under consideration. With the Pilot Chart of the North Atlantic Ocean for March there was issued a Supplement descriptive of water-spouts off the Atlantic coast of the United States during January and February. Additional interest and importance have been given to the facts, there grouped together and published, by their evident bearing upon the conditions that gave rise to the tremendous increase of violence attendant upon the approach of this trough of low barometer toward the coast. In it were given descriptions, in greater or less detail, of as many as forty water-spouts reported by masters of vessels during these two months, at various positions off the coast, from the northern coast of Cuba to the Grand banks; and since that Supplement was published many other similar reports have been received. Moreover, it was pointed out that the conditions that gave rise to such remarkable and dangerous phenomena are due to the interaction between the warm moist air overhanging the Gulf stream and the cold dry air brought over it by northwesterly winds from the coast, and from over the cold inshore current, and the greater the differences of temperature and moisture, the greater the resulting energy of action. Reports were also quoted showing that the Gulf Stream was beginning to re-assert itself after a period of comparative quiescence during the winter months, and with increasing strength and volume was approaching its northern limits, as the sun moved north in declination.

Such, then, were the meteorological conditions off the coast, awaiting the attack of the advance guard of this long line of cold northwesterly gales,—conditions still further intensified by the freshening gale that sprung up from the southeast at its approach, drawing re-enforcements of warm, moist ocean air from far down within the tropics. The energy developed when storm systems of only ordinary character and severity reach the Atlantic on their eastward march toward northern Europe is well-known, and need not be referred to further: let us now return to the consideration of this storm which is advancing toward the coast at the rate of about 600 miles a day, in the form of a great arched squall whose front is more than a thousand miles in length, and which is followed, far down the line, by northwesterly gales and temperatures below the freezing point.

The Night of the 11th–12th.

Sunday afternoon, at 3 o'clock, the line of the storm center, or trough, extended in a curved line, convex to the east, from Lake Ontario down through New York State and Pennsylvania, along about the middle of Chesapeake Bay to Norfolk, across North Carolina to Point Lookout, and thence down through eastern Florida to Key West. Northeasterly, easterly, and southeasterly gales were therefore felt all along the coast from the Gulf of St. Lawrence to the Florida Keys, except in the bight between Lookout and Cañaveral, where the barometer had already reached and passed its lowest point and the wind was northwest, with much cooler weather. Reference to the Barometer Diagram shows pretty clearly that the trough passed Norfolk a short time before it reached Hatteras, where the lowest reading was undoubtedly lower, the evening of the 11th, than it was at Norfolk.

By 10 P. M. the line has advanced as far east as the 74th meridian. Telegraphic reports are soon all in from signal stations along the coast. The barometer is rising at Hatteras and Norfolk and still falling at Atlantic City, New York, and Block Island, but there is little or no indication of the fury of the storm off shore along the 74th meridian, from the 30th to the 40th parallel, where the cold northwesterly gale is sweeping over the great warm ocean current, carrying air at a temperature below the freezing point over water above 75° Fahrenheit, and where the barometer is falling more and more rapidly, the gale becoming a storm, and the storm a hurricane. Nor are there any indications that the area of high barometer about Newfoundland is slowing down, blocking the advance of the rapidly increasing storm, and about to hold the center of the line in check to the westward of Nantucket for days, which seem like weeks, while a terrific northwest gale plays havoc along the coast from Montauk Point to Hatteras, and until the right flank of the line has swung around to the eastward far enough to cut off the supply of warm moist air pouring in from the southeast. Long before midnight the welcome "good night" message has flashed along the wires to all the signal stations from the Atlantic to the Pacific slope, whilst at sea, aboard scores of vessels, from the little fishing-schooner and pilot-boat to the great transatlantic liner, a life-or-death struggle with the elements is being waged, with heroism none the less real because it is in self-defence, and none the less admirable because it cannot always avert disaster.

The accompanying Track Chart gives the tracks of as many vessels as can be shown without confusion, and illustrates very clearly where data for this discussion are most complete, as well as where additional information is specially needed. Thus it is here plainly evident that vessels are always most numerous to the eastward of New York (along the transatlantic route), and to the southward, off the coast. To the southeastward, however, about the Bermudas, there is a large area from which comparatively few reports have been received, although additional data will doubtless be obtained from outward-bound sailing vessels, upon their return. Of all the days in the week, Saturday, in particular, is the day on which the greatest number of vessels sail from New York. The 10th of March, for instance, as many as eight transatlantic liners got under way. Out in mid-ocean there were plowing their way toward our coast, to encounter the storm west of the 50th meridian, one steamship bound for Halifax, five for Boston, nineteen for New York, one for Philadelphia, one for Baltimore, and two for New Orleans. Northward bound, off the coast, were six more, not to mention here the many sailing vessels engaged in the coasting or foreign trade, whose sails whiten the waters of our coasts.

Of all the steamships that sailed from New York on the 10th, those bound south, with hardly a single exception, encountered the storm in all its fury, off the coast. Eastward-bound vessels escaped its greatest violence, although all met with strong head winds and heavy seas, and, had the storm not delayed between Block Island and Nantucket on the 12th and 13th, would have been overtaken by it off the Grand banks. Without quoting in detail the reports received, let us see what they indicate regarding the general character of the storm during the night, preparatory to our consideration of the weather chart for 7 A. M. March 12th. To do so, be it remembered, is a very different task from that which is involved in the study and comparison of observations taken with standard instruments at fixed stations ashore. Here our stations are constantly changing their positions; different observers read the instruments at different hours;

the instruments themselves vary greatly in quality, and while some of them may have been compared with standards very recently, there are others whose errors are only approximately known. Moreover, when a vessel is pitching and rolling in a storm at sea, in imminent danger of foundering, it is, of course, impossible to set the vernier of the barometer scale and read off the height of the mercury with very great precision. It will thus be readily understood that the many hundreds of observations carefully taken and recorded for the Hydrographic Office by masters of vessels are necessarily more or less discordant, although the results obtained rest on the averages of so many reports that the probable error is always very small. An exhaustive study of reports from vessels at various positions along the coast, from the Straits of Florida to Sandy Hook, together with the records of the coast stations of the U. S. Signal Service, indicates a continuous eastward movement of the trough of low barometer during the night, accompanied by a rapid deepening of the depression. All along the coast we have the same sequence of phenomena, in greater or less intensity, according to the latitude of the vessel, as we noticed here in Washington that Sunday afternoon, when the warm southeasterly wind, with rain, died out, and after a short pause a cold northwesterly gale swept through the city, piling up the snow in heavy drifts, with trains belated or blockaded, and telegraphic communication cut off almost entirely with the outer world. It was a wild, stormy night ashore, but it was ten-fold more so off the coast, where the lights at Hatteras, Currituck, Assateague, Barnegat, and Sandy Hook mark the outline of one of the most dangerous coasts the navigator has to guard against. To bring the scene vividly before the mind would require far more time than I have at my disposal, and I can only regret that I cannot quote a few reports to give some idea of the violence of the storm.

By means of a careful comparison of many reports, it is evident that although the general trough-like form of the storm remained, yet another secondary storm center, and one of very great energy, formed off shore, north of Hatteras, as soon as the line had passed the coast. It was this center, fully equal to a tropical hurricane in violence, and rendered still more dangerous by freezing weather and blinding snow, which raged with such fury off Sandy Hook and Block Island for two days,—days likely to be long memorable along the coast. Its long continuance was probably due to the retardation of the center of the line, in its eastward motion, by the area of high barometer about Newfoundland; thus this storm center delayed between Block Island and Nantucket while the northern and southern flanks of the line swung around to the eastward, the advance of the lower one gradually cutting off the supply of warm moist air rushing up from lower latitudes into contact with the cold northwesterly gale sweeping down from off the coast between Hatteras and Montauk point. So far as the ocean is concerned, the 12th of March saw the great storm at its maximum, and its wide extent and terrific violence make it one of the most severe ever experienced off our coast.

The deepening of the depression is well illustrated by the fact that the lowest reading of the barometer at 7 A. M. was 29.88, at Augusta, Ga.; at 3 P. M., 29.68, at Wilmington, N. C.; at 11 P. M., on board the "Andes," 29.35; and at 7 A. M., the following morning it was as low as 29.20,—an average rate of decrease of pressure at the center of very nearly .23 in eight hours, and a maximum, from reliable observations, of .33.

March 12th, 13th, and 14th.

The Weather Chart for 7 A. M., March 12th, shows the line, or trough, with isobars closely crowded together southward of Block Island, but still of a general elliptical shape, the lower portion of the line swinging eastward toward Bermuda, and carrying with it violent squalls of rain and hail far below the 35th parallel. The high land of Cuba and Santo Domingo prevented its effects from reaching the Caribbean Sea, although it was distinctly noticed by a vessel south of Cape Maysi, in the Windward channel, where there were three hours of very heavy rain, and a shift of wind to NW by N. The isotherm of 32° F. reaches from Central Georgia to the coast below Norfolk, and thence out over the Atlantic to a point about one hundred miles south of Block Island, and thence due north, inshore of Cape Cod, explaining the fact that so little snow, comparatively, fell in Rhode Island and southeastern Massachusetts; from about Cape Ann it runs eastward to Cape Sable, and farther east it is carried southward again by the northeasterly winds off the Grand banks. These northeasterly winds are part of the cyclonic system shown to the eastward of this and the preceding chart; farther south they become northerly and northwesterly, and it will be noticed that they have now carried the isotherm of 70° below the limits of the chart. Thus this chart shows very clearly the positions of warm and cold waves relative to such cyclonic systems: first there is this cool wave in rear of the eastern cyclonic system, then a warm wave in front of the system advancing from the coast, and finally a cold wave of marked intensity following in its train.

It was probably during the night of the 12th that the lowest barometric pressure and the steepest gradients occurred. Although several vessels report lower readings, yet a careful consideration of all the data at hand indicates that about the lowest reliable readings are those taken at 10 P. M. at Wood's Holl, Mass. (28.92), Nantucket (28.93), Providence, R. I. (28.98), and Block Island (29.00). The steepest barometic gradients, so far as indicated by data at hand, are also those that occurred at this time, and are as follows, taking Block Island as the initial point and distances in nautical miles: at New London, 26 miles, the barometer stood 29.11, giving a difference of pressure in 15 miles of .063 inch; New Haven, 62 miles, 29.36, .087; New York, 116 miles, 29.64, .083; Albany, 126 miles, 29.76, .090. At 7 A. M. the following day, very low readings are also reported: New Bedford, Mass., 28.91, Block Island, 28.92, and Wood's Holl, 28.96.

The chart for 7 A. M., March 13th, shows a marked decrease in the intensity of the storm, although the area over which stormy winds are blowing is still enormous, comprising, as it does, almost the entire region charted. From the Great Lakes and northern Vermont to the northern coast of Cuba the wind is blowing a gale from a direction almost invariably northwest, whilst westerly winds and low temperatures have spread over a wide tract of ocean south of the 40th parallel. North of this parallel, the prevailing winds are easterly, the isobars extending in a general easterly and westerly direction. At the storm center off Block Island the pressure is 28.90, but the gradients are not so steep as on the preceding chart, and the severity of the storm, both ashore and at sea, has begun to diminish. About this center, too, the isobars are noticeably circular in form, showing that, although it first formed as an elliptical area, it gradually assumed the character of a true revolving storm, remaining almost stationary between Block Island and Nantucket until it had actually "blown itself out," while the great storm of which it was a conspicuous but not essential part was continuing its eastward progress. The enormous influx of cold air brought down by the long continued northwesterly gale is graphically shown on this chart by the large extent and deepening intensity of the blue tint, where the temperatures are below the freezing point. From the northwestern to the southeastern portion of the chart we find a difference in temperature of more than 80° F. (from below –10° to above 70°); the steepest barometric gradient is found to the northwest of Block Island, where the pressure varies 1.80 inches in 750 miles (gradient, .036 inch in 15 nautical miles), and .66 inch in 126 miles (Block Island to Albany, N. Y.; gradient, .079).

On the chart for 7 A. M., March 14th, the depression off Block Island has almost filled up, and the stormy winds have died out and become light and variable, with occasional snow squalls. The other storm center has now regained its ascendency, and is situated about two hundred miles southeast from Sable Island, with a pressure about 29.3. The great wave of low barometer has overspread the entire western portion of the North Atlantic, with unsettled squally weather from Labrador to the Windward Islands. The area of high pressure in advance has moved eastward, to be felt over the British Isles from the 17th to the 21st of the month, followed by a rapid fall of the barometer as this great atmospheric disturbance moves along its circuit round the northern hemisphere. The isotherm of 32° is still south of Hatteras, reaching well out off shore, and thence northward, tangent to Cape Cod, as far as central Maine, and thence eastward to St. Johns, Newfoundland. Great contrasts of temperature and pressure are still indicated, but considerably less marked than on the preceding chart, and the normal conditions are being gradually restored.

Conclusion.

The great storm that has thus been briefly described, as well as can be done from the data now at hand and in the limited time at our disposal, has furnished a most striking and instructive example of a somewhat unusual class of storms, and this on such a grand scale, and in a part of the world where the data for its study are so complete, that it must long remain a memorable instance. Instead of a more or less circular area of low barometer at the storm center, there is here a great trough of "low" between two ridges of "high," the whole system moving rapidly eastward, and including "within the arc of its majestic sweep," almost the entire width of the temperate zone. The "trough phenomena," as an eminent meteorologist has called the violent squalls, with shifts of wind and change of conditions at about the time of lowest barometer, are here illustrated most impressively. Such changes are, of course, to be expected and guarded against in every storm, and sailors have long ago summed them up, to store away in memory for practical use when occasion demands, in the well-known lines,—

"First rise after low
Indicates a stronger blow."

One thing to which attention is particularly called is the fact that storms of only ordinary severity are likely, upon reaching the coast, to develop greatly increased energy. As has been already pointed out, there can be no doubt but that this is especially so in a storm of this kind, where the isobars are elongated in a north and south direction. The accompanying Barometer Diagram, if studied in connection with the Track Chart and the Weather Chart for March 11th, illustrates very clearly this deepening of the depression at the storm center. The formation and persistency off Block Island of a secondary storm center of such energy as was developed in this case, however, it would seem wholly impossible to have foretold, and a prediction to that effect made under similar circumstances would probably prove wrong in at least nine cases out of ten. But it may be safely said that the establishment of telegraphic signal stations at outlying points off the coast is a matter of great importance, not only to our extensive shipping interests, but to the people of all our great seaboard cities as well. To the northward, telegraphic reports from such stations would furnish data by which to watch the movement of areas of high barometer, upon which that of the succeeding "low" so largely depends; and to the southward, to give warning of the approach and progress of the terrific hurricanes which, summer after summer, bring devastation and destruction along our Gulf and Atlantic coasts, and of which this great storm is an approximate example and a timely reminder. In this connection, also, there is another important result to be gained: scientific research and practical inventive genius, advancing hand in hand for the benefit of mankind, have discovered not only the laws governing the formation of the dense banks of fog that have made the Grand Banks dreaded by navigators but also the means by which certain facts may be observed, telegraphed, charted, and studied a thousand miles away, and the occurrence of fog predicted with almost unfailing accuracy, even whilst the very elements themselves are only preparing for its formation. By means of such predictions, the safety of navigation along the greatest highway of ocean traffic in the world would be vastly increased,—routes traversed yearly at almost railway speed by vessels intrusted with more than a million human lives, and property of an aggregate value of fully a billion dollars. What is everybody's business is too often nobody's business, and if no single nation is going to undertake this work, an international congress should be formed to do so, with full authority to act and power to enforce its decisions.

Probably nothing will more forcibly attract the attention of the practical navigator than the new and striking illustrations which have been furnished by reports from various masters of vessels, caught in the terrific winds and violent cross seas of this great storm, relative to the use of oil to prevent heavy broken seas from coming on board. Although this property of oil has been known from time immemorial, it has only recently come into general use, and it is good cause for congratulation, considering the great benefits to be so easily and so cheaply gained, that the U. S. Hydrographic Office is acknowledged to have taken the lead in the revival of knowledge regarding it, and in its practical use at sea. It is difficult to select one from among the many reports at hand, but the following brief extract from the report made by boat-keeper Robinson, in behalf of the pilots of New York pilot-boat No. 3 (the "Charles H. Marshall"), cannot fail to be read with interest. The gallant and successful struggle made by the crew of this little vessel for two long days and nights against such terrific odds is one of the most thrilling incidents of the storm, and well illustrates the dangers to which these hardy men are constantly exposed.

The "Charles H. Marshall" was off Barnegat the forenoon of the 11th, and, as the weather looked threatening, two more reefs were put in the sails and she was headed to the northward, intending to run into port for shelter. During the afternoon the breeze increased to a strong gale, and sail was reduced still further. When about 18 miles S.E. from the lightship, a dense fog shut in, and it was decided to remain outside and ride out the storm. The wind hauled to the eastward toward midnight, and at 3 A. M. it looked so threatening in the N.W. that a fourth reef was taken in the mainsail and the foresail was treble-reefed. In half an hour the wind died out completely, and the vessel lay in the trough of a heavy S.E. sea, that was threatening every moment to engulf her. She was then about 12 miles E.S.E. from Sandy Hook lightship, and in twenty minutes the gale struck her with such force from N.W. that she was thrown on her beam ends; she instantly righted again, however, but in two hours was so covered with ice that she looked like a small iceberg. By 8 A. M. the wind had increased to a hurricane, the little vessel pitching and tossing in a terrific cross-sea, and only by the united efforts of the entire crew was it possible to partially lower and lash down the foresail and fore-staysail. No one but those on board can realize the danger she was in from the huge breaking seas that rolled down upon her; the snow and rain came with such force that it was impossible to look to windward, and the vessel was lying broadside to wind and sea. A drag was rigged with a heavy log, anchor, and hawser, to keep her head to sea and break the force of the waves, but it had little effect, and it was evident that something must be done to save the vessel. Three oil bags were made of duck, half filled with oakum saturated with oil, and hung over the side forward, amidships, and on the weather quarter. It is admitted that this is all that saved the boat and the lives of all on board, for the oil prevented the seas from breaking, and they swept past as heavy rolling swells. Another drag was rigged and launched, although not without great exertion and danger, and this helped a little. Heavy iron bolts had to be put in the oil bags to keep them in the water, and there the little vessel lay, fighting for life against the storm, refilling the oil bags every half hour, and fearing every instant that some passing vessel would run her down, as it was impossible to see a hundred feet in any direction. The boat looked like a wreck; she was covered with ice and it seemed impossible for her to remain afloat until daylight. The oil bags were replenished every half hour during the night, all hands taking turn about to go on deck and fill them, crawling along the deck on hands and knees and secured with a rope in case of being washed overboard. Just before midnight a heavy sea struck the boat and sent her over on her side; everything movable was thrown to leeward, and the water rushed down the forward hatch. But again she righted, and the fight went on. The morning of the 13th, it was still blowing with hurricane force, the wind shrieking past in terrific squalls. It cleared up a little towards evening, and she wore around to head to the northward and eastward, but not without having her deck swept by a heavy sea. It moderated and cleared up the next day, and after five hours of hard work the vessel was cleared of ice, and sail set for home. She had been driven 100 miles before the storm, fighting every inch of the way, her crew without a chance to sleep, frost-bitten, clothes drenched and no dry ones to put on, food and fuel giving out, but they brought her into port without the loss of a spar or a sail, and she took her station on the bar as usual.

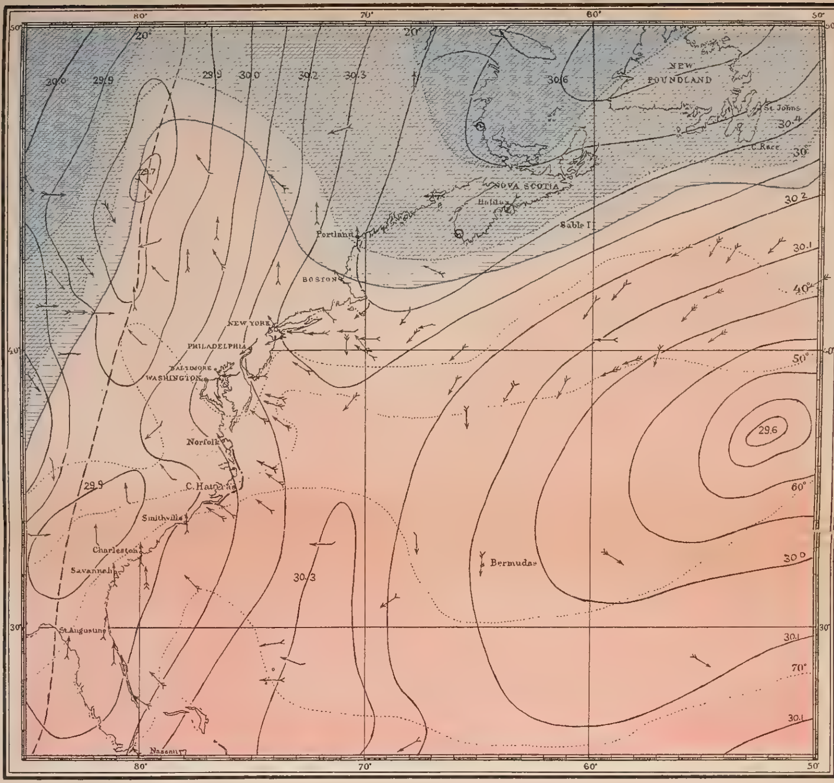
Do the pages of history contain the record of a more gallant fight! Nothing could show more graphically than this brief report, the violence and long duration of the storm. No wonder that this terrific northwest gale drove the ocean itself before it, so that the very tides did not resume their normal heights for nearly a week at certain ports along the coast, and the Gulf Stream itself was far south of its usual limits. The damage and destruction wrought ashore are too fresh in mind to be referred to here, and losses along the coast can only be mentioned briefly. Below Hatteras there was little damage done to shipping. In Chesapeake Bay, 2 barks, 77 schooners, and 17 sloops were blown ashore, sunk, or damaged; in Delaware Bay, 37 vessels; along the New Jersey coast and in the Horse-shoe at Sandy Hook, 13; in New York harbor and along the Long Island coast, 20; and along the New England coast, 9. The names of six vessels that were abandoned at sea have been reported, and there are at least nine others missing, among them the lamented New York pilot boats "Phantom" and "Enchantress," and the yacht "Cythera." Several of these abandoned vessels have taken their places amongst the derelicts whose positions and erratic tracks are plotted each month on the Pilot Chart, that other vessels may be warned of the danger of collision; the sch. "W. L. White," for instance, started off to the eastward in the Gulf Stream, and will soon become a source of anxiety to the captains of steamships along the transatlantic route, and furnish a brief sensation to the passengers when she is sighted. There is thus an intensely human side to the history of a great ocean storm, and to one who reads these brief records of facts and at the same time gives some little play to his imagination, there is a very pathetic side to the picture. In the words of Longfellow,—

"I see the patient mother read,
With aching heart, of wrecks that float
Disabled on those seas remote,
Or of some great heroic deed
On battle fields, where thousands bleed
To lift one hero into fame.
Anxious she bends her graceful head
Above these chronicles of pain,
And trembles with a secret dread
Lest there, among the drowned or slain,
She find the one beloved name."

WEATHER CH

WEATHER CHART.—MARCH 11.

Meteorological conditions at noon, Greenwich mean time (7 A. M., 75th meridian time).



Barometer.—Isobars in full black lines for each tenth of an inch, reduced pressure. The trough of low barometer is shown by a line of dashes.

Temperature.—Isotherms in dotted black lines for each ten degrees Fahr. Temperatures below freezing (32° F.) in shades of blue, and above freezing in red.

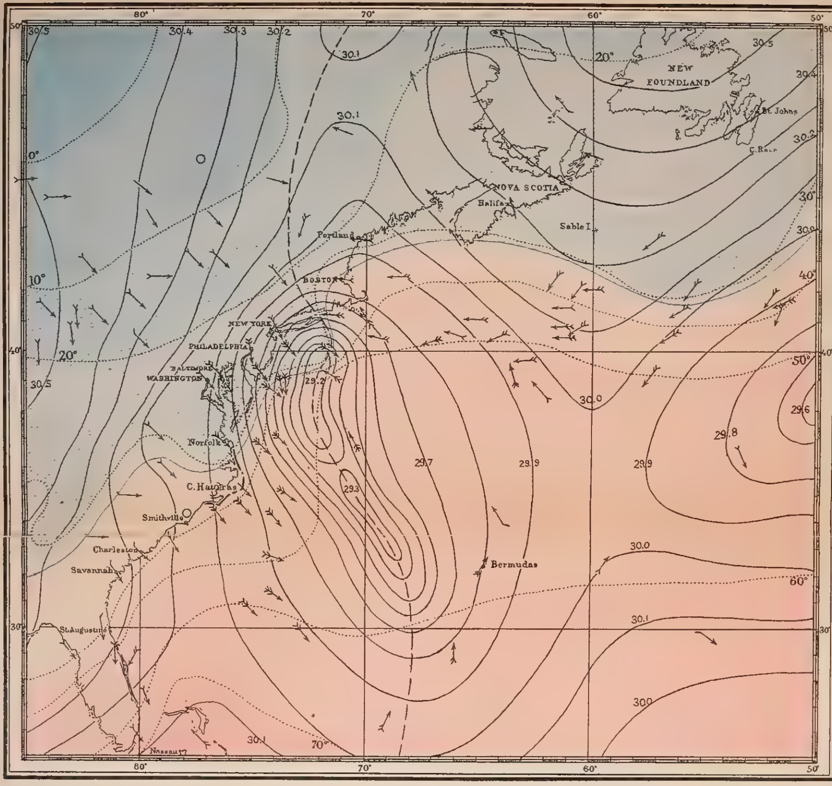
Wind.—The small black arrows fly with the wind at the position where each is plotted. The force of wind is indicated in a general way by the number of feathers on the arrows, according to the scale given in the following table:

Plotted on Chart.	Force, by Scales in practical use.					Pounds per square foot.	Miles per hour.	Kilometers per hour.	Meters per second.
	0 — 12	0 — 10	0 — 8	0 — 7	0 — 6				
O Calm.	0	0	0	0	0	0.	0.	0.	0
1	1 — 2	1 — 2	1	1 — 2	1	0. — .40	0. — 9.	0. — 14.1	0 — 4
2	3 — 4	3 — 4	2	3 — 4	2	0.41 — 2.53	9.1 — 22.5	14.5 — 36.2	4 1 — 10 1
3	5 — 7	5 — 6	3 — 4	5	3	2.54 — 8.20	22.6 — 40.5	36.3 — 65.2	10 2 — 18 1
4	8 — 10	7 — 8	5 — 6	6	4 — 5	8.21 — 22.90	40.6 — 67.5	65.3 — 108.7	18 2 — 30 1
5	11 — 12	9 — 10	7 — 8	7	6	22.91 and over.	67.6 and over.	108.8 and over	30 2 and over.

It will be noticed that the Beaufort scale (0–12), in general use at sea, has been converted into the international scale (0–10) for the sake of clearness in plotting data on the chart. The absence of arrows over large areas indicates absence of simultaneous data; at sea, however, this has been partly compensated for in the construction of the chart by information obtained from journals and special storm reports of vessels in the vicinity.

WEATHER CHART.--MARCH 12.

Meteorological conditions at noon, Greenwich mean time (7 A. M., 75th meridian time).



Barometer.—Isobars in full black lines for each tenth of an inch, reduced pressure. The trough of low barometer is shown by a line of dashes.

Temperature.—Isotherms in dotted black lines for each ten degrees Fahr. Temperatures below freezing (32° F.) in shades of blue, and above freezing in red.

Wind.—The small black arrows fly with the wind at the position where each is plotted. The force of wind is indicated in a general way by the number of feathers on the arrows, according to the scale given in the following table:

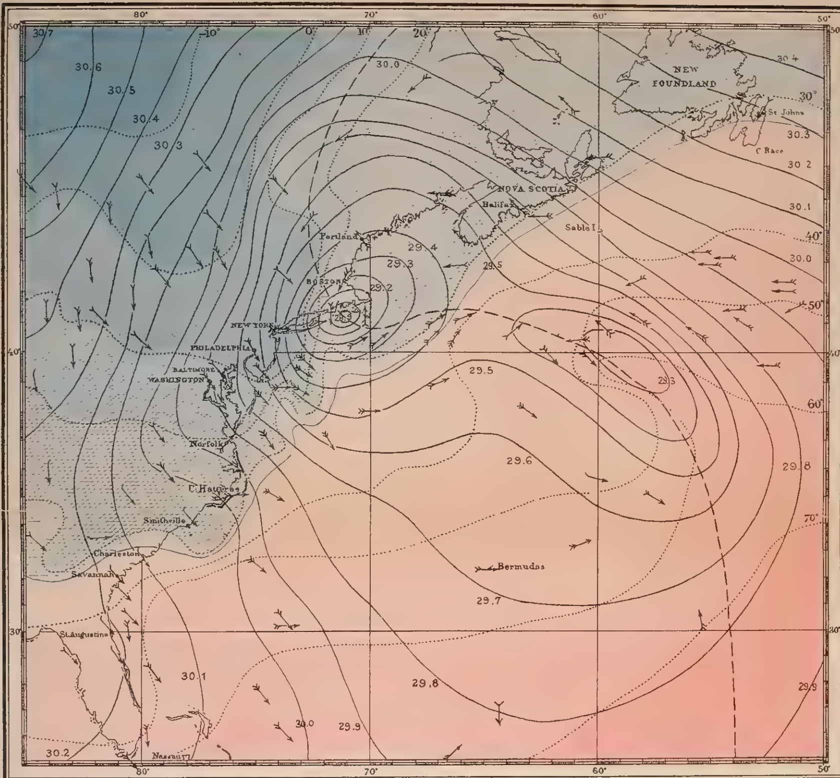
Plotted on Chart.	Force, by Scales in practical use.					Pounds per square foot.	Miles per hour.	Kilometers per hour.	Meters per second.
	0 — 12	0 — 10	0 — 8	0 — 7	0 — 6				
○ Calm.	0	0	0	0	0	0.	0.	0.	0
1	1 — 2	1 — 2	1	1 — 2	1	0. — .40	0. — 9.	0. — 14.4	0. — 4.
2	3 — 4	3 — 4	2	3 — 4	2	0.41 — 2.53	9.1 — 22.5	14.5 — 36.2	4.1 — 10.1
3	5 — 7	5 — 6	3 — 4	5	3	2.54 — 8.20	22.6 — 40.5	36.3 — 65.2	10.2 — 18.1
4	8 — 10	7 — 8	5 — 6	6	4 — 5	8.21 — 22.90	*40.6 — 67.5	65.3 — 108.7	18.2 — 30.1
5	11 — 12	9 — 10	7 — 8	7	6	22.91 and over.	67.6 and over.	108.8 and over.	30.2 and over.

It will be noticed that the Beaufort scale (0–12), in general use at sea, has been converted into the international scale (0–10) for the sake of clearness in plotting data on the chart. The absence of arrows over large areas indicates absence of simultaneous data; at sea, however, this has been partly compensated for in the construction of the chart by information obtained from journals and special storm reports of vessels in the vicinity.

Smithville
30°

WEATHER CHART.--MARCH 13.

Meteorological conditions at noon, Greenwich mean time (7 A. M., 75th meridian time).



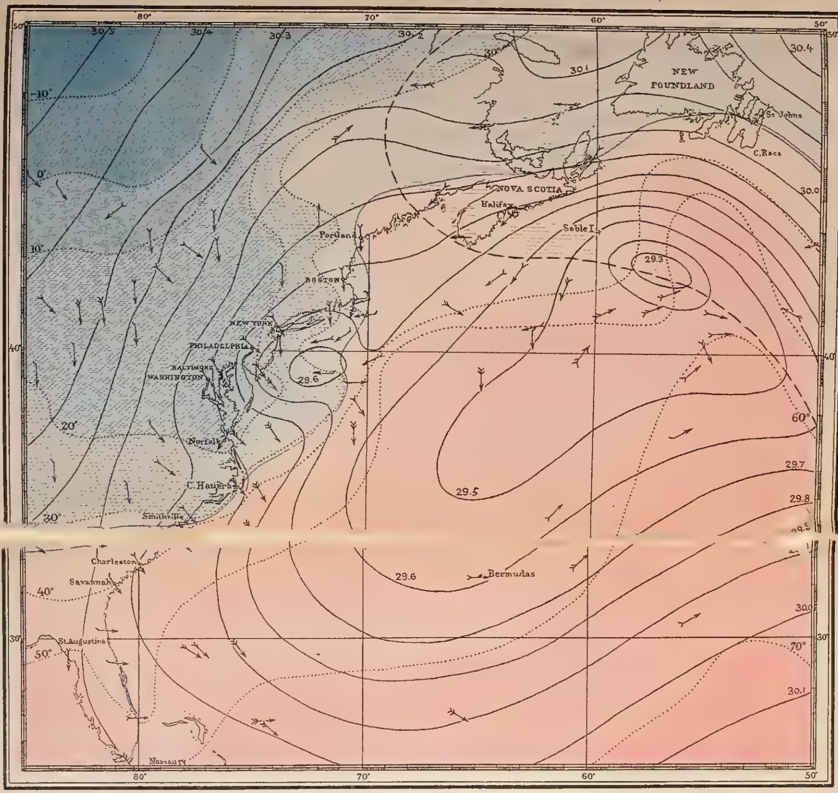
Barometer.—Isobars in full black lines for each tenth of an inch, reduced pressure. The trough of low barometer is shown by a line of dashes.
Temperature.—Isotherms in dotted black lines for each ten degrees Fahr. Temperatures below freezing (32° F.) in shades of blue, and above freezing in red.
Wind.—The small black arrows fly with the wind at the position where each is plotted. The force of wind is indicated in a general way by the number of feathers on the arrows, according to the scale given in the following table:

Plotted on Chart.	Force, by Scales in practical use.					Pounds per square foot.	Miles per hour	Kilometers per hour.	Meters per second.
	0 — 12	0 — 10	0 — 8	0 — 7	0 — 6				
O Calm.	0	0	0	0	0	0.	0.	0.	0.
1	1 — 2	1 — 2	1	1 — 2	1	0. — .40	0. — 9.	0. — 14.4	0. — 4.
2	3 — 4	3 — 4	2	3 — 4	2	0.41 — 2.53	9.1 — 22.5	14.5 — 36.2	4.1 — 10.1
3	5 — 7	5 — 6	3 — 4	5	3	2.54 — 8.20	22.6 — 40.5	36.3 — 65.2	10.2 — 18.1
4	8 — 10	7 — 8	5 — 6	6	4 — 5	8.21 — 22.90	40.6 — 67.5	65.3 — 108.7	18.2 — 30.1
5	11 — 12	9 — 10	7 — 8	7	6	22.91 and over.	67.6 and over.	108.8 and over	30.2 and over.

It will be noticed that the Beaufort scale (0–12), in general use at sea, has been converted into the international scale (0–10) for the sake of clearness in plotting data on the chart. The absence of arrows over large areas indicates absence of simultaneous data; at sea, however, this has been partly compensated for in the construction of the chart by information obtained from journals and special storm reports of vessels in the vicinity

WEATHER CHART.—MARCH 14.

Meteorological conditions at noon, Greenwich mean time (7 A. M., 75th meridian time).



Barometer.—Isobars in full black lines for each tenth of an inch, reduced pressure. The trough of low barometer is shown by a line of dashes.

Temperature.—Isotherms in dotted black lines for each ten degrees Fahr. Temperatures below freezing (32° F.) in shades of blue, and above freezing in red.

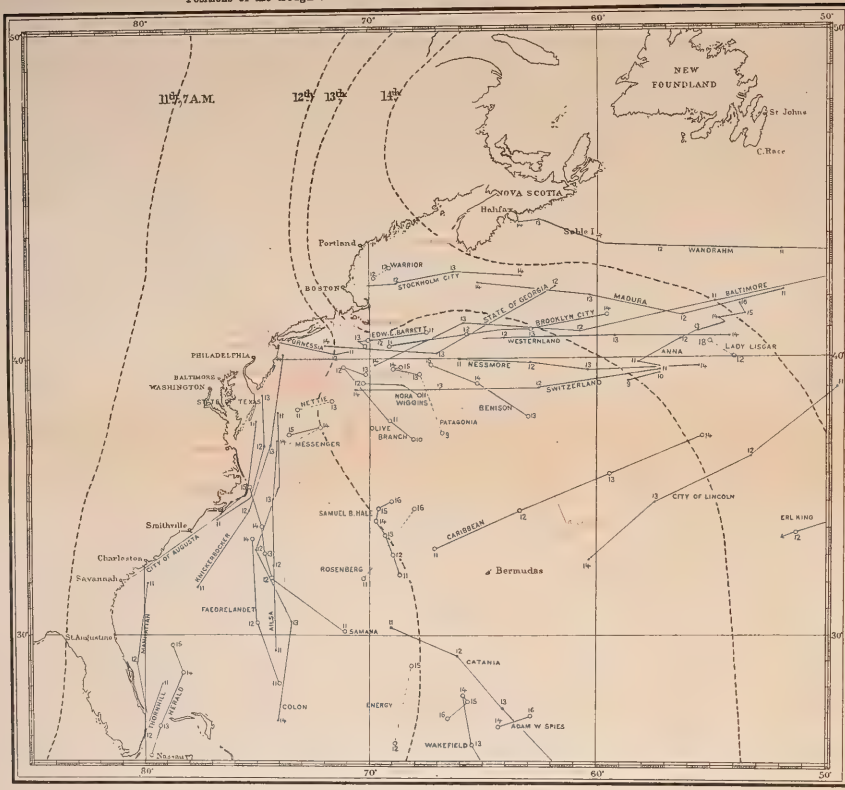
Wind.—The small black arrows fly with the wind at the position where each is plotted. The force of wind is indicated in a general way by the number of feathers on the arrows, according to the scale given in the following table:

Plotted on Chart.	Force, by Scales in practical use.					Pounds per square foot.	Miles per hour.	Kilometers per hour.	Meters per second.
	0 — 12	0 — 10	0 — 8	0 — 7	0 — 6				
O Calm.	0	0	0	0	0	0.	0.	0.	0
1	1 — 2	1 — 2	1	1 — 2	1	0. — .40	0. — 9.	0. — 14.4	0. — 4
2	3 — 4	3 — 4	2	3 — 4	2	0.41 — 2.53	9.1 — 22.5	14.5 — 36.2	4.1 — 10.1
3	5 — 7	5 — 6	3 — 4	5	3	2.54 — 8.20	22.6 — 40.5	36.8 — 65.2	10.2 — 18 1
4	8 — 10	7 — 8	5 — 6	6	4 — 5	8.21 — 22.90	40.6 — 67.5	65.3 — 108.7	18.2 — 30 1
5	11 — 12	9 — 10	7 — 8	7	6	22.91 and over.	67.6 and over.	108.8 and over.	30.2 and over.

It will be noticed that the Beaufort scale (0–12), in general use at sea, has been converted into the international scale (0–10) for the sake of clearness in plotting data on the chart. The absence of arrows over large areas indicates absence of simultaneous data; at sea, however, this has been partly compensated for in the construction of the chart by information obtained from journals and special storm reports of vessels in the vicinity.

TRACK CHART.

Positions of the trough of low barometer and tracks of vessels, March 11–14, 1888.



Positions at 7 A. M. (Greenwich noon) are indicated on the chart by a point; at noon, ship's time, by a small circle.

Black.—The line of dashes indicates the position of the trough of low barometer, or the line of sudden change from easterly to westerly winds, with brief intervals of calm, shifts of wind in heavy squalls of rain or snow, colder, and, finally, clearing weather.

Red.—Positions and names of land stations and names and tracks of vessels plotted in red are those whose barometer curves are shown in the accompanying Barometer Diagram.

Blue.—The tracks of certain other vessels from which storm reports have been received are plotted in blue. In addition to these, however, storm reports have been received from the following vessels, omitted from the chart in order to avoid confusion:

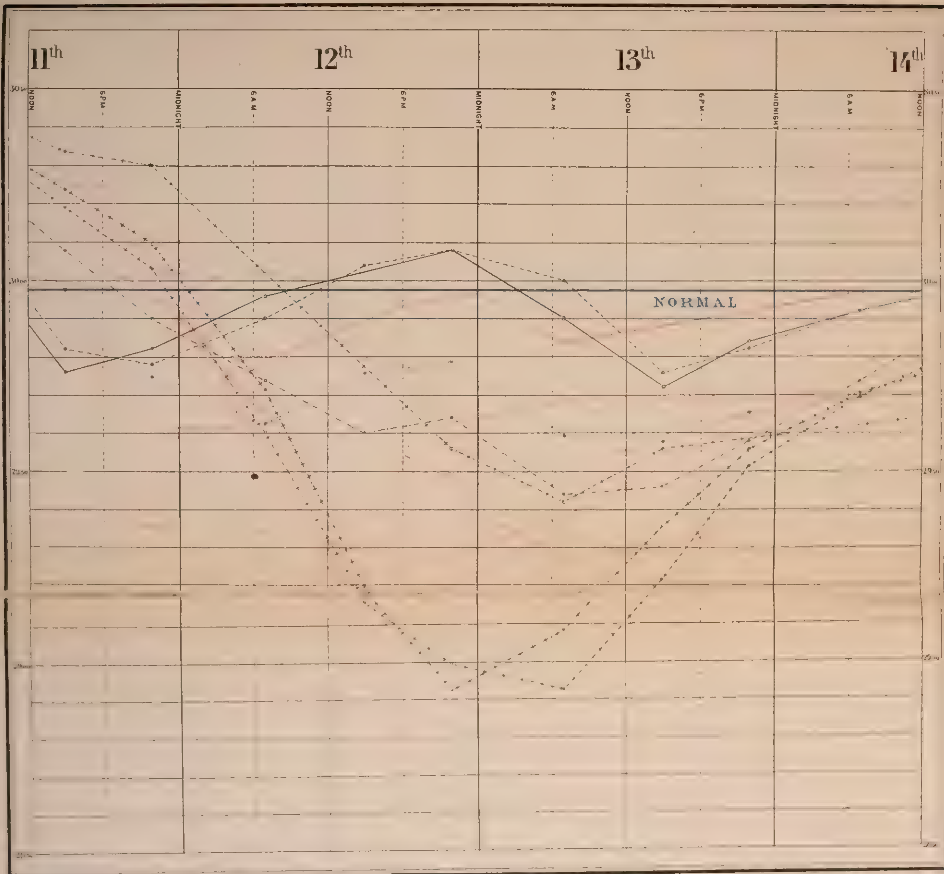
Transatlantic steamships, westward bound: Glendevon, Lydian Monarch, St. Ronans, Werra.

Coasting steamships, bound south: El Monte, Morgan City, New Orleans. *Bound north:* Newport.

Sailing vessels off the coast from Montauk point to cape Cañaveral: Spartan, Charles H. Marshall, Caprice, Coryphene, Phebe, Isaac Orbeton, John H. Krantz, Arcot, Iroquois, Welaka, Serene, Warren B. Potter, Normandy, Lottie Stewart, Melissa Trask, Wilhelm Birkedal, Johanna, James S. Stone, Anita.

BAROMETER DIAGRAM.

Illustrating the fluctuations of the barometer from noon, March 11, to noon, March 14 (75th meridian time).



Barometer Curves.—As it is only practicable to illustrate graphically the barometer records of a few vessels and land stations, the following have been selected as being of special interest; the small circles mark the points of observation:

SIGNAL STATIONS.

- Norfolk.
- Hatteras.
- Atlantic City.
- New York.
- Block Island.
- Nantucket.
- Yarmouth, N. S.

VESSELS.

- British steamship Andes.
- American schooner Kensett.
- British steamship Lord Clive.
- American schooner Lida Fowler.
- American schooner George Walker.
- British steamship Serapis.
- British ship Glenburn.

Barometer Normal.—The barometer normal for the 5°-square from latitude 35° to 40° N., longitude 65° to 70° W., assumed for the present purpose as the normal for the entire area, is 29.98, and is indicated by the blue line on the diagram.

The positions of the above-mentioned signal-stations and the tracks of these seven vessels are all indicated in red on the accompanying Track Chart. This diagram should therefore be studied in connection with the chart, in order to form a clear idea of the general eastward movement of the trough of low barometer, and the accompanying rapid deepening of the depression upon reaching the coast.

THE SURVEY OF THE COAST.

BY HERBERT G. OGDEN.

At the inception of the Coast and Geodetic Survey in the early years of the century, so little was known of the dangers attending navigation along our extensive seaboard, that those who engaged in commercial enterprises were constrained to rely upon local knowledge and the reports of the hardy navigators who might carry their ventures to success. The charts available were by no means a sure reliance, and it has since been shown, contained many serious errors. The great headlands and outlying shoals that present the greatest obstacles to the safety of coastwise navigation, had not been carefully surveyed, and their relative positions to one another were only approximately determined.

The capacities of the harbors had not been ascertained, many were unknown; and even at the great port of New York, the Gedney or Main channel, was not developed until after the permanent establishment of the Survey in 1832, and the thorough exploration of the entrance was undertaken. A list of the sunken dangers and new channels that have been discovered during the progress of the work would fill pages. It is true such developments were to be expected in making a precise survey of the comparatively uncharted coast; but they, nevertheless, clearly point to the necessity of the work. We may also assume that the men who were controlling the destinies of the republic, realized that a knowledge of the coast was essential if they would succeed in building up a commerce, without which it was believed the prosperity of the people could not be assured. The deep draught vessels of the present day could not have traded along our shores on any margin of safety with the little that was known, and it is largely due to the perfect charting of the coast, that commercial enterprise has found it practicable to build the larger vessels of modern type to meet the increasing demands of trade.

The survey proposed was also required in providing for the public defence; as it is a self-evident proposition, that if we would protect a harbor from a hostile fleet, we must know not only the channels by which the fleet might enter, but their relations to each other and the points of vantage that should be utilized in obstructing them; and in modern warfare to know these things only approximately will not suffice, for precision is practiced now in the art of war, as well as in the arts of peace.

The lack of charts of our extensive Coast line, or indeed, of any practical information that could be utilized in a systematic defence against foreign aggression, was only one of the many perplexities that surrounded our forefathers in building the nation. By their valor they had wrested a jewel from the British Crown, and had inaugurated a system of government by the people, which on their sacred honors they had sworn to defend. But not a generation had passed away when they saw new dangers, and were forced to contemplate again taking up arms in defence of their rights. The land was theirs, even far towards the setting sun, pioneers had explored it, and they knew whence might come a hostile foe. But of the waters from far away to the eastward, that flowed on until they washed every shore and filled the great Bays, even to the heart of the Republic, they knew little, save that over that almost immeasurable expanse might come the fleet of destroyers to penetrate they knew not where, and inflict incalculable damage months ere the dreary tales might be told. It must be remembered there were no telegraphs, no railroads, no steamboats, in those days, and time taken by the forelock was time gained. The speed of man could not be overtaken as we see it to-day in the wondrous inventions of the last generations. Each community was dependent upon itself, alone, in time of danger, to ward off the blow or yield to a more powerful foe; assistance could hardly be obtained in months and perhaps not then. It was not possible for any man to study or to learn the points of danger, and prepare a system of defence.

President Jefferson in his far-seeing statesmanship, threatened with war, realized the danger. A survey of the coast he believed essential to the national defence, and to the prosperity of the nation in time of peace. Had his wise counsels prevailed and the survey been prosecuted with vigor, instead of being almost immediately suspended for a quarter of a century, there can be no question but that it would have saved the people millions of dollars in expenditures and put other untold millions into their coffers, through the impetus it would have given to commerce years before commerce actually had a name in many that are now thriving seaport towns.

But it is not to be supposed the commercial importance of a knowledge of the coast and harbors was underrated because the Survey was not prosecuted. The people were poor, the task would be expensive and laborious. The appliances for the work were not in the possession of the Government, and above all, war came came sooner than was anticipated and the energies of the people were taxed to the utmost in combat with their powerful foe ; and when peace came again, there was the inevitable commercial depression that follows a resort to arms. The men of the day fully realized how illy they were prepared to invite commerce to our shores, or incite our own people to more extensive trade. There was nothing to adequately represent those magnificent harbors that have since become famous the world over ; nor of that long line of coast with its treacherous shoals, whereby those seeking new ventures might judge of the dangers to be encountered. The absolute ignorance that existed was aptly described in the Albany Argus in 1832, when the propriety of reviving the act of 1807 was under discussion, as follows :

"It had been discovered by an American statesman that parent countries always keep the commercial knowledge of their colonies as a leading-string in their own hands, and that as practical navigators, American seamen knew less of their own shores than the country and its allies from whose subjection we had recently delivered ourselves by force of arms. In large vessels, three nations, the Dutch, the French, and the English, approached our harbors with less risk than those bearing our own flag ; at the same time that in small and more manageable vessels, we had long been known as a match for the strongest. The president, Jefferson, saw the defect and the manner in which it must be remedied. We were at that time on the brink of war, about whose justice some of our politicians differed in opinion and it was, of course, more necessary to pray for a fortunate result than to preach the causes which had occasioned the quarrel. To have procured for the nation (even had it been practicable so to do) the old charts from the Dutch, French, and English governments, would have only been to put our knowledge on a par with theirs, while to execute more recent and accurate surveys, was advancing the new country above the old. With the clear and bold perception, which always distinguishes men of genius when they are entrusted in times of danger with the destinies of a nation, the president recommended a survey of the whole coast with all the aid of the more recent discoveries of science."

The proposed survey was strongly advocated by President Jefferson, and the Secretary of the Treasury, Mr. Gallatin, and in February, 1807, Congress passed the first act providing for the work. Thirteen separate plans, or schemes, were submitted for consideration ; among the number was one by Professor F. R. Hassler, which was finally adopted, and Professor Hassler was appointed the first superintendent. It is not necessary to dwell, in detail, upon the varying fortunes of the survey during the three-quarters of a century that have passed since the original act authorizing it. The first thirty years of experiment, before it was finally established as a bureau of the Treasury Department, show only too clearly the ignorance and prejudice against which the supporters—we may say founders—of the survey had to contend. But they had only the experience of all men who attempt the inauguration of new things of which it cannot be shown that they will return a cash profit at the end of six months. To the opponents of the measure cash could not be seen at all, and the profit, whatever it should be, was only an intangible kind of benefit to be realized in the future by additional security to their property and commerce ; but, in reality, as has since been appreciated, the direct saving of many millions of dollars annually.

The war of 1812 interrupted Professor Hassler's labors and it was not until 1817 that he actually commenced work ; but he was stopped the next year by a limitation of the law requiring the work to be performed by the Military Departments. In 1832 Congress passed a special act reviving the law of 1807 and Professor Hassler was again appointed Superintendent. A further interruption occurred in 1834 by the transfer of the bureau to the Navy Department, but this was of short duration, as it was re-transferred to the Treasury Department in 1836, where it has since remained. Professor Hassler continued as Superintendent until his death in November, 1843. He was succeeded by Professor A. D. Bache, who was fortunate in assuming the charge under much more favorable auspices than had prevailed under his predecessor.

By the appropriation bill passed in March, 1843, the President was directed to appoint a Commission to reorganize the Bureau and prescribe methods for its future conduct. The plan recommended by the Commission was substantially that which had been followed by Professor Hassler. It was approved by the President a few months before Professor Bache assumed the superintendency and has since been the law for the execution of the work. To have a law specifying in detail the methods that should be employed in prosecuting the surveys, that had been drawn by a special commission of experts and approved by the administration, relieved the Superintendent of much of the responsibility that had been borne by Professor Hassler, although it did not put an end to the carpings of the critics, or their advocacy of the less expensive "nautical surveys."

The reorganization provided for the employment of civilians and officers of the Army and Navy to serve directly under instructions from the Superintendent; thus securing for the service the opportunity to procure the best talent from either civil or military life. The civil element, it was assumed, would form a body of experts for the prosecution of those branches of the work not properly falling in the direct line of the military, and experience has demonstrated that while the results anticipated have been fully realized, the organization has not only proved effective but conducive to the advancement of the survey in many ways. The Civil War was a serious interruption, but alone, proved the wisdom of the civil organization of the Bureau. On the outbreak of hostilities the military element was necessarily withdrawn for duty with the Army and Navy; and it was not until ten years after the close of the war that officers of the Navy were again available, while officers of the Army, through the exigencies of the Military service, have not returned at all.

The organization was preserved through these fifteen years by the permanent civil nucleus, and the work suffered no deterioration, but steadily advanced, notwithstanding that the larger number of the civilians were constantly employed during the four years of the war with the Armies and Navy, in different capacities on the staffs of commanding officers; and that the urgent necessities of the government devolved additional labor, and temporarily, a new class of work upon the office force in compiling, draughting and publishing maps of the interior for the use of the Armies in the field. And when finally, our Armies were disbanded and our fleets reduced to a peace basis, and officers of the Navy resumed the execution of the Hydrographic work, it was but to step into the duties of their predecessors; they had, too, the additional advantage of the fifteen years' experience of the purely civil administration of the Survey, during which time the trained surveyors of the land had become equally expert as surveyors of the water, and had added not a little to the improvement of Hydrographic methods. The History of the Survey shows a steady advance in methods of work from its foundation to the present day. But so equally has the march of improvement been due to the zeal and untiring efforts of the civilians and officers of the Army and Navy alike, that any distinction would be invidious.

The plan of reorganization of 1843 provided for a detailed survey of precision. It was to be based on an exact triangulation that would insure positive results, that the location of a danger or the development of a new channel, should be beyond doubt; and that the survey, when completed, should fit together as one continuous line, in which the distance and direction of any object on the map from any other object should be true, whether the objects were in hailing distance of one another, or at the extremes of our boundaries. So well was the scheme conceived, so perfect has it proved in operation, that it is substantially the guide for the closing labors of the great work, notwithstanding the many improvements that experience has wrought in the details.

Those engaged upon the Survey have been quick to profit by experience, and the master mind of Professor Bache, the second Superintendent, was not slow to adopt that which promised increased economy, rapidity or improvement. He drew from all sources, Science contributed her quota and the great inventive genius of the American people played an equal share in producing the final results.

The researches that were necessary to obtain the information required by law "for completing an accurate chart of every part of the coasts," have produced results of great economic and scientific value to the whole people, aside from their bearing on the interests of commerce and navigation; and which will contribute to the welfare of mankind long years after those who labored for them have passed away. A brief reference to a few of the many instances that might be cited to illustrate this perpetual influence to benefit our fellow men, may not be without interest to some of you present.

The application of the method of determining latitude by the measurement of small zenith distances, introduced by Captain Andrew Talcott of the Engineer Corps, U. S. A., while serving as an Assistant on the Survey, developed such radical errors in the star places given in the catalogues, that it led to an almost immediate call for better places, and arrangements were made with the observatories of the country to obtain the necessary observations, the Survey to pay for the labor involved. Stimulated by the knowledge that better work was required to meet the new demand, observatories deficient in instruments procured new ones, and soon furnished more accurate star places. Continued observation has added still further improvement until to-day we have catalogues that furnish the highest degree of precision. Professor Chauvenet defines "Talcott's method" as "one of the most valuable improvements in practical astronomy of recent years, surpassing all previous known methods (not excepting that of Bessel by prime vertical transits) both in simplicity and accuracy." But the advantages of the method have been found to be of a practical nature also; as it is productive of large economy in time and labor and has reduced the cost of the Survey many thousands of dollars.

The introduction of the Electric Telegraph was utilized by the Survey immediately on the practical accomplishment of the first line built, as a ready and improved means for determining longitude. Indeed, before Professor Morse had demonstrated to the world the truthfulness of his theories and experiments, the bare possibility of their success, and availability in the instant transmission of time, had been discussed on the Coast Survey, and the method to be first employed fully considered. But as in the application of all things under new conditions, experience is the teacher, and improvements were frequently made, until finally the invention and perfection of the "chronograph" has brought the method to a degree of precision that little more can be looked for. This method of determining longitude, introduced, fostered and perfected on the Coast Survey, has been more far reaching than geographical boundaries. All civilized nations have adopted it as the "American Method," and by the greater accuracy and reliability of the results the whole world has profited. The saving that has accrued by the more perfect determination of longitudes and the consequent increased safety to commerce, may be counted by millions every year; until one stands aghast in contemplation of the immensity of the sum, and fears to reckon it, even approximately, much less to prophecy what it may reach in the future. The system is but a natural sequence of the development of the telegraph, but emphasizes in a marked degree the spirit of progress that has ever been the active principle and guide in the conduct of the work, and advanced its methods to a state of perfection that has called forth the admiration of the scientific world.

The determination of the magnetic elements has been a subject of investigation from the early days of the survey; the knowledge sought was essential to the navigator, and in recent years, especially, has proved to be of the greatest practical value on shore. Limited by small appropriations the research was at first slow. But a trust fund left by Professor Bache, who always evinced the warmest interest in this particular investigation, added largely to the rapidity with which observations could be obtained, until now we have magnetic maps of the United States of such reasonable precision that they are authoritative, and are in almost daily demand. The results are more far reaching than their mere tabulation for the current year, as laws have been determined by which the declination in a locality can be ascertained for any year in the past.

There are but few places where the needle remains stationary, or points in the same direction, for any great length of time; it even changes daily and during the hours of a day; but the aggregate for a year will rarely exceed three or four minutes of arc. If we reflect then, upon the great use made of the compass in the settlement of the continent, and the proverbial neglect of the country surveyor of those days to record the local variation, or declination, with his work, we may see a little of the utility and practical purposes to which the results are constantly being applied. Property so little thought of a hundred years ago that a few acres more or less, lost or acquired, in its transfer defined by compass surveys, may suddenly assume a value in these days of progress that every square foot is worth dollars. When a dispute arises, deeds are examined, lost or obliterated marks are diligently sought for, perhaps one is found, surveyors are employed to run out the lines but only make the confusion worse. Instead of a few rods that were in doubt according to the best information, the surveyor's line makes it acres, and litigation looms up to eat the profits of the sudden rise, and there seems even then no satisfactory solution of the vexing problem. How valuable then must be the fact, that it is possible to compute the variation for years back, to the time the original survey was made, and furnish the deflection that will re-run the lines so clearly as to render the descriptions in the deed intelligible. This is but a single instance of the practical application of the knowledge gained; and if its general usefulness may be judged by the numerous inquiries made of the Bureau, it is not unreasonable to assume that time will bear increasing testimony of its great economic value from those who traverse the land, as well as those who sail on the waters.

The study of the recurrence of the tides along our extensive Coast lines, and determination of laws that would satisfy the great variance in the different periods, was a problem of no little magnitude but the greatest possible importance to our commerce. Much of the traffic along the coasts literally moves with the tides, and the cost of transportation is enhanced or diminished as the tide retards or advances it. Hundreds of dollars of expense may be incurred on a single cargo that must enter on the high water, but through imperfect knowledge of the master of the ship, is forced after sighting his port, to wait for the next tide, perhaps over night, and is driven to sea by a sudden storm and the voyage made several days longer. Such mishaps are not infrequent, and even at the great port of New York certain classes of vessels must "wait for the tide." The investigation of this complex subject has resulted in the acquirement of a knowledge that enables the prediction of the time of high and low water, and the height of the tidal wave, years in advance; and the mariner may now carry with him the tables published on the subject wherever he goes, and be independant of the doubtful communications he may otherwise receive from the shore. How many lives, how many dollars, have been saved by the knowledge gained?

But the investigation of the Tidal phenomena is of great scientific importance also; and a practical assistance in the great problems involved in the preservation and improvement of our harbors, but in this connection it probably falls more properly under the head of that greater study of the currents and their effects in the erosion, and building of the shores; the movement of the sands and formation of shoals and channels; termed "Physical Hydrography." Our commerce depends largely on this study for its perpetuation, for without harbors commerce must cease; and without harbors that will admit vessels of the largest class it must deteriorate. If commerce finds increased profits in large vessels it demands increased facilities, and the bars to the harbors with but six or eight feet of water on them a few years ago, must have ten, perhaps fifteen feet now, or the people must suffer their trade to pass to some more fortunate or energetic neighbor. This may be a hardship ; but the demands of trade are inexorable, the profits must be reasonably assured, and those who would have the trade must comply with the requirements. Thus we see the striving for harbor improvements ; the weakest making the greatest outcry that they shall not be left in the race. And the improvements must come in the end, or at least be attempted, for it is as much a law of commerce not to be hampered by small freights, as it is the law of nature that water flows down hill.

The outcry for "improvements" never grows weaker; it is the expression of a sincere conviction that the life of the community and the welfare of the "back country" depend upon its success for prosperity; it will not admit a rebuff and knows no such word as failure. Alleged authorities are consulted, a scheme of improvement is proposed and Congress is asked to vote the money, and finally the improvements are attempted. To be successful, the plan must conform to known general laws and the peculiarities of local conditions, many of which are only ascertainable by comparison of surveys at different periods. Theories advanced on data collected by one survey, may be strengthened or disproved by the facts ascertained in a subsequent survey; and it is only when the plan proposed meets the general laws and the local conditions at the same time, that it holds out promise of success. The study of the questions involved has been greatly aided by the work of the Coast Survey in improvements already attempted, and will be of greater assistance in the future. A positive knowledge of what the local conditions were when a harbor was at its greatest capacity, is of the greatest help in indicating the improvements necessary to restore it, after deterioration, or to maintain it in the full measure of its usefulness. Reliable charts do this, but they tell only half the story. A cause must be found for the effects that have been produced, and the remedy suggested must overcome that cause or control it, that it may work good instead of evil. In Physical Hydrography we learn the forces that nature has given us in the tides, the currents and the winds, and divert them from powers of destruction, as man in his ignorance may have led them, or in their warfare with one another they may have led themselves;

and bring their mighty influence to protect, improve or maintain that which we originally had. Many harbors have suffered incalculable injury through the recklessness of these who live upon them, and whose daily bread is dependent upon their preservation; until the evil has become so great that commercial cities have now "Harbor Commissions," whose special function is the preservation and improvement of the harbors. The original surveys made by Coast Survey are the foundations on which they very generally must build, while re-surveys point out to them the obstacles that must be overcome. And thus it will ever be; and future generations endeavoring to meet the demands of commerce for increased facilities, will have still greater cause for thankfulness, that the wise men who inaugurated the work of the Coast Survey, determined that it should be executed with every improvement that science could devise; and that the able men who conducted it, did not yield to the clamor for quick returns and cheap results, of only momentary value. They will realize by the benefits they will derive from it, as do those now living who have watched its progress and development, that the best is the cheapest as it will be useful through all time.

In 1871 Congress authorized the execution of a Geodetic triangulation across the continent to connect the great primary triangulations along the Atlantic and Pacific coasts, and provided that the triangulation should determine positions in those States that made requisite provision for topographical and geological surveys of their own territories. Each year since then, a small sum has been expended on these works with gratifying results to the States that have availed themselves of the assistance. But it was not until 1878 that Congress designated the Bureau as the "Coast and Geodetic Survey," the official title it bears at this time. Many comments have been passed upon the action of Congress in extending the field of the survey to the interior in the establishment of a "Geodetic Survey," which has been looked upon as a purely scientific research for which the people had no immediate use, and could well afford to wait. But if the tree can be judged by its fruit, there will be no lack of testimony to the economic value of the Geodetic Survey in the near future; aside from its scientific and practical usefulness in perfecting the Survey of the Coasts. It will eventually be the basis for a precise survey of the whole country, determining boundaries, settling disputes, and furnishing incontrovertible data by which later generations can reproduce the marks placed by the local surveyors who make use of it, should they become obliterated or lost; thereby causing a direct increase in the security of property boundaries, and diminution in litigation that now costs millions of dollars annually. Some of the practical advantages to be derived from such a work, are now being demonstrated in Massachusetts in the "Town boundary Survey," as it is called, in which the corners, or turning points of the boundaries are being determined trigonometrically in a subsidiary work based upon the Geodetic triangulation of the Coast Survey. Each boundary corner in this scheme becomes a fixed point, and the direction and distance of many other corners are at once accurately ascertained in their true relations to it. The town boundaries will in due time be made the bases of reference for all local surveys and subdivisions of property; so that, eventually, there will be developed a cadastral map of unrivaled excellence, to supplement the Topographical map that has just been completed.

The imperfections of our "land surveys," brilliant as the scheme was conceived to be at the time of its inauguration, demonstrate only too clearly the extravagance of primitive methods in matters intended to be enduring. As time passes and property taken up under the "land survey" becomes more valuable, the difficulty of accurately identifying boundaries becomes more serious, until finally, it is only after long litigation that rights are determined. The inherent defect in the land survey to accomplish the purpose for which it was designed, lies in the fact, that while it parcels out the land, or a section of land, in a given number of lots, it fails to provide the means for identifying the boundaries of the lots at any future time; the marks placed for this purpose become obliterated or perhaps are moved by designing men, until a large area may be involved in great uncertainty. A triangulation covering the same ground and controlled by Geodetic work, determining the true positions of the old marks that may be left, would be the most economical and precise method of relieving these uncertainties and fixing for all time the location and boundaries of the lots originally parcelled out, by observations and marks that cannot be lost or obliterated.

The system of weights and measures in use throughout the country is largely due to the patient labor of the Coast Survey. Required by law to have standards of length, the only bureau in the public service that required such a measure of precision, it was in the natural order of events that the Superintendent of the Survey should also be charged with the maintenance of standards of Weight and Capacity. The duplication of standards for the use of the people was begun under Mr. Hassler, so long ago that the system has really grown with the population. Wise legislation has fostered the sentiment of uniformity until we are indeed blessed, that wherever we may be in all our broad domain, a pound is a pound, a yard is a yard, and a bushel is a bushel. Manufacturers receive their standards from the Bureau, and in special cases have their products tested and certified. And individuals engaged upon work of great refinement, seek the stamp of the Bureau, also, upon the measures on which they must rely. But so careful is the Bureau to preserve the integrity of its certificate, that the stamp is refused except on weights or measures of approved metal and workmanship. Business men realize in every day life the benefits that have been derived from the simple legislation that inaugurated a supervision over the weights and measures of the country early in her history, though they may have no conception of the endless annoyances they would have been subjected to had the preservation and duplication of standards not been provided for.

The limited time assigned to me will not permit a detailed statement of the researches made by the Bureau in all the different branches of science related to the practical conduct of the work, much less a reference, even, to the many improvements instituted in the practice of surveying. As in the case of the observatories called upon to replace their defective instruments with those more refined, to enable them to furnish star places of sufficient precision to meet the improved method of determining latitude, so has the demand ever been upon the experts employed upon the work in all its branches. The Triangulation, Topography, Hydrography, Astronomy and Magnetics have all passed through several stages of development and improvement in methods and instruments, to meet the requirements put forth by those charged with the conduct of the work, that the full measure of harmony desired should be secured and that they might supply the demands made upon them for information. Imperfect results indicate defects to be remedied, and it is to the credit of those who performed the labor, that they overcame one difficulty after another as they were developed, until now the methods and instruments in the hands of experts, will produce far superior results at a much less cost than was possible at the time the Survey was inaugurated.

The charting of the great ocean currents, has long been an interesting investigation to hydrographers the world over. A sketch of the efforts, projects, and devices that have been resorted to by the Coast Survey in the attempt to unravel the mysteries of the Gulf Stream, would exemplify the continuous demand for improvement and new exertions under which those employed upon the work have always labored, although the full measure of knowledge sought has not yet been obtained. But it is not necessary to enter into these details at this time; let it suffice that many experiments and failures pointed out the path to be followed by subsequent observers, and stimulated to new efforts, until at last appliances have been perfected that have already produced wonders, and it is safe to predict, will ere many years show the ocean currents on the charts of the world with the same relative precision that the currents in a river or harbor can now be indicated. Lieutenant Maury gave us current charts that were a marvel in their day, but his information, or data, was defective, and his conclusions, therefore, only approximate; and how to improve on the data he had, has ever since been the subject of research. The depth of the ocean is necessarily an important factor in the study of its features, as erroneous depths lead to false hypotheses. The introduction by the English of a method of sounding with a wire, has therefore proved an important advance. American officers have perfected the apparatus and severely tested the methods, demonstrating the reliability of the results and the total unreliability of the old deep sea soundings taken with a line. These accurate wire soundings have revealed new facts, disproved old theories and formed new ones to guide future researches. So successful is the improved apparatus that specimens of the bottom of the ocean have been brought up from a depth of five miles. The great value of this system, however, is not confined to the mere ascertainment of depths for the hydrographer and cartographer, as may be readily demonstrated by referring to the reports of the Fish Commissioner. A further step towards improving on Maury's results; the crowning glory that is to shed light on much that has been dark, and trace out those ocean currents we have heretofore vainly endeavored to follow, is found in the invention and devices of a naval officer attached to the Survey, whereby he can anchor the ship in mid-ocean and observe the direction and velocity of the current as from a stationary body, and with a "current meter," also his own invention, determine the same factors hundreds of feet below the surface; thus ascertaining not only the movement at the surface, but the depth of the body of water that moves, and the velocity at various depths, so that finally we have the volume—a quantity—to be followed until it meets other currents or is absorbed in the vast expanse. Already current observations have been recorded with the ship anchored at the great depth of eighteen hundred fathoms; and arrangements have been perfected that it is believed will prove successful at the greater depth of three thousand fathoms. It is impossible with our superficial knowledge of the great ocean currents to estimate the benefits that will be derived from their systematic exploration. It is not probable that the absolute determination of their limits would produce such a revolution in navigation, as was caused by Maury's wind charts, but it is reasonably certain they would prove a valuable assistance to the navigator, and in the great channels and bays of the world increase his facilities for the successful navigation of his ship. Not a little of their value, perhaps the larger part, will be of an indirect nature, resulting from their study by investigators in the natural sciences interested in utilizing the bounties of nature for benefit of man.

The Survey was instituted for the determination of facts, and the presentation of them in an intelligible form. It does not promulgate theories, and has no use for them beyond the assistance they may be in indicating the line of research necessary to ascertain the facts; but rather leaves to the student the formulation of the theories that may be deduced from the facts presented. The publications of the Survey are, therefore, calculated to contain only useful, practical information, on the subjects of which they treat. An examination of them will show this to be the case, and further, that error has more likely been committed by over-caution, than a too free use of the material at command. Doubtless much has been suppressed through lack of means, as it has always been the aim of the Superintendents to expend the appropriations in producing the most useful results, whether in surveys to be made or facts to be published. It necessarily requires many years to complete a precise survey over a large area; and in the work of the Coast Survey, with the people in all sections of our extended coast line petitioning for surveys at the same time, the problem was beset with additional difficulties. Fortunately Congress prescribed the method on which the work should be conducted, and that the method permitted making surveys widely separated with the certainty that they could eventually be joined and form a consistent whole. Soon after the plan of reorganization of 1843 had been adopted, surveying parties were on the Atlantic and Gulf coasts at many points; the principal harbors and headlands with outlying shoals were first surveyed and it was but a few years before charts of them were published. The less important shores between these points were left for future work, but Hydrographic examinations or Nautical surveys, were made of them, and preliminary charts of long stretches of coast were issued, to be followed when the surveys had been completed by the finished chart of reliable data. So elastic was the system adopted for the conduct of the work, that its availability was limited only by the annual appropriations. Soon after the annexation of Texas surveying parties were on that coast, and on the acquisition of California a few years subsequently parties were soon at work there also; and after the close of the war and purchase of Alaska, the immense field thus opened was attacked with equal promptness, and a reconnaissance made that resulted in a map of considerable accuracy. As the precise surveys were extended the charts and plans published from the preliminary surveys were withdrawn, the new charts necessarily having later dates.

The original surveys of the Atlantic and Gulf coasts are now practically completed, but very little more remaining to be done in a few comparatively unimportant localities. On the Pacific coast precise surveys supplemented by careful reconnaissance of less important sections, define nearly the whole outline, excepting Alaska, but a great deal of work is still required to obtain the full measure of information necessary to accurately chart it. And in Alaska, Nautical surveys have developed long stretches of the "Inland passage" and the most important anchorages, supplementing the general reconnaissance of the whole coast line. A very large proportion of our shores, however, are subject to such radical changes from natural causes, that the survey of the coast can never be brought to final completion. Examinations and re-surveys are as essential as was the original work, if the material already acquired is to be maintained in the full measure of its usefulness, and commerce is to continue to reap the legitimate benefit of the expenditures already incurred. Fortunately the survey has been conducted on such sound principles it meets the increasing requirements for accuracy demanded by the navigation of to-day, as fully as it did the more simple needs of the navigator of forty years ago, and it is fairly believed, whatever may be the necessities of the future, that it will still supply the information desired.

The Surveys are published in four hundred and fifty charts designed to meet the various needs of the Navigator and Civil Engineer, for either general or local purposes ; over thirty thousand copies of these are issued annually and there is a steadily increasing demand.

The assistance rendered to the armies and fleets of the Union, in the late Civil War, is a chapter in the history of the Survey that should not be forgotten. The office in Washington was beset with demands for information from all over the country, for descriptions not of the coast alone, but all sections of the interior representing the seat of war. Fortunately the experts were there who, under the direction of able chiefs, could collect and compile such material as was available. The labor of the office in this cause resulted in the publication of a series of "War Maps" of the interior, for which there is frequent demand even at the present day. This was all additional work to a force already overburdened in the preparation of manuscript maps and special information, compiled from the reports of the Field parties ; especially of those localities that had only recently been surveyed. And in all the din and excitement of the call to arms, with hosts of stalwart, honest men assembled around him, that might give in their learning the wisdom of the world, the controlling mind of the Survey, that had labored diligently and sought knowledge patiently, was a chosen counsellor of the Chief of the Nation. Declining military honors, the profession in which he had been educated, he devoted himself with renewed energy to assisting the nation's efforts in those special duties he knew so well how to perform. A patriot himself of the purest type, he inspired those around him by his ennobling spirit and zeal in the cause.

An average of twenty parties were maintained with the Army and Navy during all the years of the war, rendering services of acknowledged value to the military forces. An officer of the Coast

Survey piloted the fleet into Port Royal; another led the Iron Clads in the attack on Sumter; a third stationed the fleet in the bombardment of Jackson and St. Philip; and a fourth rendered signal services in the assault on Fort Fisher. They were on the Peninsula, guides in the wilderness on the retreat to Malvern Hill; at Chickamauga, Knoxville, Missionary Ridge; the march to the Sea and pursuit through the Carolinas; on the Red river; before Petersburgh; in the Sounds of North Carolina; the Sea Islands of Georgia and Florida and the swamps of Louisiana; and, wherever they went, few in numbers though they were, they gained honor for their cause and credit for their Chief.

The Survey of the Coast has excited the admiration of the whole civilized world for its thoroughness and accuracy, and has not been excelled by the most advanced nations. It has justly been claimed to be a scientific work, as well as a practical one, for science has guided those who have conducted it and led them through the fields of their labors on the only sure basis to produce knowledge. And the great knowledge that has been acquired by its scientific prosecution, is beyond comparison with the little that would have resulted had it been conducted on the less thorough methods of Nautical Surveying that have been so earnestly advocated. We cannot compute the value of what has been learned in dollars and cents; that it has saved to the Nation many times over, all that it has cost, does not admit of a doubt. Its educational influence has been widespread, extending beyond the seas, and coming back to us with cheering words of encouragement and praise. Practical men utilizing the results of the great work in the business affairs of life, use no stinted phrases in the encomiums they bestow upon it; Military men compelled to rely upon it in the perils of warfare, have not found it wanting, and have given only praise for the great help it was to them; Scientific men, ever watchful of that which is true, have approved it the world over, and cite it as an example of the great profit that may come to a people, free to utilize Science in the conduct of practical work. Our institutions of learning have adopted its publications in text-books. Our merchants venture millions of dollars daily on the veracity of its statements, and our mariners risk their lives on the truthfulness of the Surveys. It has added to the prosperity of the nation in peace—to her glory in war; and when history shall record its awards to our people, there will be no page of the galaxy with more honor than that which bears tribute to the genius of American Science, in the work of the Coast Survey. From ignorance most profound we have been raised to knowledge almost perfect; and well may the commercial communities by their associations and exchanges bear the testimony to its value that they do, and have done in times past; as might the whole people for the wise legislation that established the work, that has defended it, and we may hope will perpetuate it for its inestimable benefits to them all.

THE SURVEY AND MAP OF MASSACHUSETTS.

By Henry Gannett.

The Geological Survey is engaged in making a map of the United States. This work was commenced as an adjunct to the geological work, and was rendered necessary by the fact that, except in limited areas, no maps of the country on any but the smallest scales were in existence. While these maps are thus primarily made to aid in the geologic work and in the delineation of geologic results, they are being made of such a character as to meet all requirements which topographic maps on their scales should subserve.

The work is being carried on in various parts of the country and is being prosecuted on a considerable scale, the annual output being between 50,000 and 60,000 sq. miles of surveyed area. Commenced in 1882, the work has been extended over more than 300,000 sq. miles at the present time. Of this work the survey of Massachusetts forms a part.

In some of its features this survey was an experiment. It was the joint work of the State and the United States, and, so far as I know, was the first example of such joint work. In the summer of 1883 the U. S. Geological Survey commenced topographic work within the State, the scale adopted being very nearly 2 miles to an inch. Only a beginning was made during the season, and in the following winter the Governor of the State recommended to the legislature that if practicable advantage be taken of the opportunity, and an arrangement for coöperation be made between the State and the Geological Survey, by which a map upon a larger scale and with a greater degree of detail might be obtained as a result of this survey. Accordingly, after some correspondence with the Director of the U. S. Geological Survey, the legislature authorized the appointment of a commission, with power to make an arrangement with the Director of the Geological Survey looking toward the result above indicated, and appropriated $40,000, being half the estimated cost of the survey upon the larger scale, $10,000 of which was to be available the first year and $15,000 in each of the two subsequent years. The following is the text of the bill, which is in many respects a model legislative document:

COMMONWEALTH OF MASSACHUSETTS.

Resolve to Provide for a Topographical Survey and Map of the Commonwealth. (Chapter 72, 1884.)

Resolved, That the governor, with the advice and consent of the council, be and is hereby authorized to appoint a Commission to consist of three citizens of the Commonwealth, qualified by education and experience in topographical science, to confer with the director or representative of the United States Geological Survey, and to accept its coöperation with this Commonwealth in the preparation and completion of a contour topographical survey and map of this Commonwealth hereby authorized to be made. Said Commission shall serve without pay, but all their necessary expenses shall be approved by the governor and council, and paid out of the treasury. This Commission shall have power to arrange with the Director or representative of the United States Geological Survey concerning this survey and map, its scale, method, execution, form and all details of the work in behalf of the Commonwealth, and may accept or reject the plans of the work presented by the United States Geological Survey. Said Commission may expend in the prosecution of this work a sum equal to that which shall be expended therein by the United States Geological Survey, but not exceeding ten thousand dollars, during the year ending on the first day of June, eighteen hundred and eighty-five, and not to exceed the sum of fifteen thousand dollars in any one year thereafter, and the total cost to the Commonwealth of the survey shall not exceed forty thousand dollars.

In pursuance of this resolution Gov. Robinson appointed the following gentlemen as commissioners on the part of the State : Gen. Francis A. Walker, President of the Massachusetts Institute of Technology, Mr. Henry L. Whiting, Assistant U. S. Coast and Geodetic Survey and Prof. N. S. Shaler of Harvard College. The Director of the Geological Survey, upon being notified of this action, laid before the commissioners a proposition for a joint survey in the following terms :

1. It is proposed to make a topographic map of the State of Massachusetts, the expense of which shall be borne conjointly by the Geological Survey and the State of Massachusetts.

2. The Borden triangulation and the Coast and Geodetic Survey triangulation will be utilized as far as possible, and additional triangulation will be made to such extent as may be necessary.

3. The topographic work of the Coast and Geodetic Survey will be utilized as far as it extends.

4. The survey will be executed in a manner sufficiently elaborate to construct a topographic map on a scale of 1 : 62,500.

5. The topographic reliefs will be represented by contour lines with vertical intervals varying from ten to fifty feet, as such intervals are adapted to local topography.

6. As sheets are completed from time to time copies of the same will be transmitted to the commission.

7. When the work is completed and engraved for the Geological Survey, the Commission, or other State authorities, may have, at the expense of the State, transfers from the copper plates, thus saving the State the cost of final engraving.

8. The survey will be prosecuted at the expense of the Geological Survey for the months of July, August and September. During the last half of the month of September the Commission shall examine the work executed up to that time, and if the results, methods and rates of expenditure are satisfactory to the Commission, the expenses of the work for the month of October shall be borne by the State of Massachusetts, for the month of November by the Geological Survey, and the work thereafter shall continue to be paid alternately by months, by the Geological Survey, and the State of Massachusetts severally. But as the larger expense incident to the beginning of the work is imposed on the Geological Survey, at the close of the work the State of Massachusetts shall pay such additional amount as may be necessary to equalize the expenditures; provided that the total expenditure of the State of Massachusetts shall not exceed forty thousand dollars ($40,000); and if the completion of the survey of the State of Massachusetts and the preparation of the necessary maps on the plan adopted by the survey shall exceed in amount eighty thousand dollars ($80,000), then such excess shall be wholly paid by the Geological Survey.

The commissioners suggested some minor amendments to this proposition, which were accepted, and under these provisions work was commenced and carried forward continuously to its completion. The field work of the state was finished with the close of the season last fall, and the drawing of the maps is now substantially done. The work was done in the field with such accuracy and such degree of detail as to warrant the publication of the map upon a scale of one inch to a mile, or, what is practically the same thing, 1:62,500. The relief of the surface is represented by the contour lines, or lines of equal elevation above sea, traced at vertical intervals of 20 feet. These contour lines, which are becoming a common feature of modern maps, add an additional element. They expresss quantitatively the third dimension of the country, viz: the elevation. An inspection of such a map not only shows the horizontal location of points, but their vertical location as well. It gives the elevations of all parts of the country represented, above the sea.

The map represents all streams of magnitude sufficient to find place on the scale, and all bodies of water, as lakes, swamps, marshes, etc. In the matter of culture, in which definition is included all the works of man, it seemed desirable to represent only such as are of a relatively permanent nature, and to exclude temporary works, for the very apparent reason that if temporary works were included, the map would be not only a constant subject for revision, but even in the interval between the survey and the publication, the culture might change to a large extent, and the published map be correspondingly incorrect from the outset. In searching for a criterion which could be consistently followed in distinguishing between culture which should and should not be represented, it was found that by limiting the representation to that which may be denominated public culture, that is, that which has relation to communities, as distinguished from individuals, a consistent line could be drawn. Adopting this criterion, the map contains all towns, cities, villages, post offices,—in short, all settlements of any magnitude, all railroads and all roads, with the exception of such as are merely private ways, all public canals, tunnels, bridges, ferries and dams. There were excluded under this ruling isolated houses, private roads, fences and the various kinds of crops, etc. Forest areas are shown. Subsequently, however, in response to the urgent wish of the commissioners, the survey consented to locate the houses upon the maps, although in the engraving these have been omitted. The omission of all private culture leaves the maps very simple and easy to interpret. For convenience the field work was done upon a larger scale than that upon which the maps were to be published, viz: a scale of 1:30,000, or a little more than double the publication scale. The map of the state as planned is comprised in 52 atlas sheets, each of which comprises 15 minutes of latitude by 15 minutes of longitude and an area of about 225 square miles. These sheets upon the scale of publication are about $17\frac{1}{2}$ inches by 13 in dimensions. In two or three cases along the coast it seemed to be in the interest of economy to vary from this arrangement slightly, in order to avoid the multiplication of sheets. Many of the sheets upon the borders of the state project over into other states, and, in cases where the area lying without the state was small, the survey was extended beyond the limits of the state, in order to complete the sheets.

Every map is a sketch, which is corrected by the geometric location of a greater or less number of points. Assuming entire accuracy in the location of the points, that is, assuming that the errors of location of the points are not perceptible upon the map, the measure of accuracy of the map consists in the number of these geometric locations per unit of surface, per square inch, if you will, of the map. The greater the number of these locations the greater the accuracy of the map, but however numerous they may be the map itself is a sketch, the points located being simply mathematical points. Whatever method be employed for making these geometric locations, the sketching is substantially the same everywhere. The methods of making these locations must differ with the character of the country, as regards the amount and form of its relief, the prevalence of forests and other circumstances. There are two general methods of making the geometric locations used in surveying; one, by triangulation; the other by the measurement of a single direction and a distance, which is the method employed in traverse surveying. In practice, the two methods are often combined with one another. Both methods have been employed in Massachusetts. The fundamental basis of the work was the triangulation which had been carried over the state by the U. S. Coast and Geodetic Survey. By this survey points were located at wide intervals over the state. Besides this there was executed between 1830 and 1840, at the expense of the state, a triangulation known as the "Borden Survey." This located a much larger number of points, but less precisely. The Coast and Geodetic Survey kindly undertook the adjustment of this triangulation to an agreement with its own work, and, as many of the lines were common to the two pieces of work, the locations made by the Borden Survey were by this adjustment greatly strengthened. Even after this work was done, however, there remained considerable areas which were destitute of located points, and it became necessary to supplement it. This was done in part by the Coast and Geodetic Survey and in part by the Geological Survey. By these several agencies upwards of 500 points were made available for the use of the topographers. These are in the main well distributed, furnishing upon each sheet a sufficiency, while upon many the number is greatly in excess of the requirements.

The work of location has been done in different parts of the state by different methods as seemed most applicable to the differing conditions of relief, forest covering and culture. Throughout most of the western part of the state the work was done entirely with the plane table, using the method of intersections as the means of location. Each plane table sheet comprised one-half of an atlas sheet, cut along a parallel of latitude. The plane tabler, starting with three or more locations upon his sheet, furnished by the triangulation, expanded over the sheet a graphic triangulation, locating thereby a considerable number of points, before commencing detailed work. This was done as rapidly as possible. consistent with a high degree of precision. The reason for covering the sheet with the graphic triangulation beforehand lay in the necessity for locating a considerable number of points before the sheet had opportunity to become distorted by alternations of moisture and drying. This done, the plane tabler went on with his usual routine of work, locating minor points and sketching the topography in contours. The map was as far as possible completed upon the stations, with the country in view. Elevations were determined as the work progressed, with the vertical circle of the alidade, and minor differences of elevation between points whose height was known were measured by aneroid barometer.

In this work several different forms of plane table have been employed. It was commenced with the large heavy movement designed I believe by the Coast and Geodetic Survey. This, however, was found unnecessarily heavy and cumbersome, and it was discovered that the requisite degree of stability could be obtained with much less weight. For this plane table movement there was soon substituted another form in use in the Coast and Geodetic Survey, which is very much lighter. This was soon improved by taking off the slow motion in azimuth, which was found to be unnecessary, and the addition of more powerful clamps, for the purposing of rendering it more stable. A still more stable form, however, coupled with even less weight, was designed by Mr. W. D. Johnson, of the U. S. G. S. and was immediately adopted. This is substantially a modification of the ball and socket movement. It consists of two cups of large size fitting closely to one another and working within one another in such a way as to allow of the adjustment in level, and the clamping of the level adjustment independently of the azimuth movement, clamps for both level and azimuth adjustments being underneath the instrument. This form is extremely stable, admits of quick adjustment and leveling, and it has been from the time of its invention in general use in this state and elsewhere in the Survey.

In the undulating, forest-covered, region in the southeastern part of the state it was found impracticable to use economically the method of intersections, and resort was had to the traverse method for making locations. In this method, as is well known, one station is located from another by the measurement of a distance and direction, the line of stations being connected at each end either upon stations in the triangulation or upon other lines, while from the stations in these traverse lines, points off the lines are located by intersections, if practicable, or by distance and direction measurement. For this kind of work the plane table, at least such a plane table as is generally in use is an inconvenient instrument. The plane table with the telescopic alidade is too cumbersome an instrument to be carried about and set up as frequently as is necessary in this work. Therefore for this purpose theodolites, fitted with stadia wires and stadia rods, have been used. Distances are measured by the angles subtended by the stadia wires upon the rod, whose divisions are of known length, while the directions are measured by the compass attached to the theodolite, and differences of elevation by spirit level and vertical angles. With this instrument lines were run along all the roads and along the principal streams in this part of the state and from these lines the country lying between them was located and sketched.

In the northeastern and in much of the middle portion of the state a mixed method of work was employed, the plane table being used for carrying on the intersection work wherever it could be done, while by traversing the roads, their details, which could not be obtained by the plane table in this region, were reached. These traverses were platted in the office and the maps drawn from notes and sketches made in the field.

The degree of accuracy of the map depends upon the accuracy of the locations, their number and the uniformity of their distribution. Of their accuracy it is only necessary to state that their errors are not sufficiently large to be appreciable upon the scale of the map, for instance the scale being one inch to a mile, an error of 50 feet in the location of a point would be upon the map but one hundredth of an inch,—a barely appreciable quantity, and it is of course easy to make the locations within this limit. Of the number of locations pér unit of map surface I shall give statistics drawn from the full experience of the Survey in this state. The area surveyed by the method of intersections exclusively comprises 3,500 square miles, or about two-fifths of the state. In this area 3,123 stations were occupied with the plane table, or slightly less than one to a square mile, or, measured upon the map, one to a square inch. Besides these, 17,846 points were located in this area by intersections, making, with the occupied stations, a total of 20,969 locations within the area, or 6.2 horizontal locations per square inch. In the same area the heights of 34,893 points were measured, being 10 per square inch. I am expressing these figures in terms of inches of the final map, because it is the map with which we are concerned.

The area surveyed by the traverse method is 2500 sq. miles. In this area 5615 miles of traverse lines were run, being 2.2 linear inches per square inch of the map. In running these lines 46,524 stations were made with the theodolite, being 8.3 per linear mile of traverse and 18.6 per sq. inch of map. The number of measurements of height was 92,561, being 37 to the square inch.

The area surveyed by the mixed method comprised 3000 sq. miles. In this 900 stations were made with the plane table, and from them 3718 points were located by intersection, making altogether 4618 points located with the plane table. In addition to this, 6767 miles of traverse were run, being 2.2 linear miles per square mile of area. In these traverses 31,708 instrumental stations were made, or 4.7 per linear mile and 10.6 per sq. mile. The sum of the plane table stations, locations, and the traverse stations, which makes up the total of horizontal locations in this area, is 36,326, being a total of 12.1 points per sq. inch of map. The number of measurements of height in this area is 67,119, being 22.4 per sq. inch. It will be seen that the number of horizontal locations and of height measurements in the area traversed is much greater than in that surveyed by the intersection method, and it might be inferred that the former work is better controlled than the latter. I do not judge, however, that this is the case, owing to the fact that traverse stations are not of as much value for purposes of location as those by intersection. The latter are selected points. The former are not selected points, but on the contrary, a large proportion of them are located simply for carrying forward the line and are of no further service, and very few of them are such as would be fitted for the purpose of controlling areas.

Within the area surveyed by traverse nearly every mile of road has been run. With the exception of those in the cities, nearly every house and every church in the commonwealth has been located, either by intersection with the plane table or by traverse.

The organization of the surveying parties has been of the simplest character. Plane table work has been carried on by one man with an assistant, the latter doing little more than attend the plane tabler and assist him in carrying the instruments. Each of these little plane table parties was furnished with a horse and buggy for transportation. The organization for traverse work has been equally simple, consisting of a traverse man and a rodman. As a horse and buggy would be an impediment in this work, this feature of the outfit has been omitted. In the mixed work the traverse men have been under the immediate control of the plane tabler, so that their movements have been directed by him in detail. The average output per working day of the plane tabler has been for the whole survey 3.1 sq. miles, and of the traverse man 2.8 sq. miles, and, as the expenses of the former have been slightly greater than those of the latter, the cost per square mile of the two methods of work has been substantially the same.

The average cost per square mile of the survey of the State has been a trifle less than $13. This includes the salaries of all men engaged upon the work during the field season, their traveling, subsistence and all other expenses, the salaries of the men engaged in drawing the maps in the office, the cost of supervision and of disbursement,—in short all expenses of whatever character, incurred in the production of the map.

PROCEEDINGS

OF THE

NATIONAL GEOGRAPHIC SOCIETY.

ABSTRACT OF MINUTES.

First Regular Meeting, Feb. 17, 1888. — Held in the Law Lecture room of Columbian University, the president, Mr. Hubbard, in the chair.

The president delivered an inaugural address.

Major J. W. Powell lectured on the Physiography of the United States.

Second Regular Meeting, March 3, 1888.—Held in the Law Lecture room of the Columbia University, vice-president Bartlett in the chair.

Paper: Patagonia, by Mr. W. E. Curtiss.

Third Regular Meeting, March 17, 1888.—Held in the Assembly Hall of the Cosmos Club, the president, Mr. Hubbard, in the chair.

Paper: Physical Geography of the Sea, by Commander J. R. Bartlett.

Fourth Regular Meeting, March 31, 1888.—Held in the Assembly Hall of the Cosmos Club, the president, Mr. Hubbard, in the chair.

Discussion was had on the proposed Physical Atlas of the United States, participated in by Messrs. Gannett, Gilbert, Ogden, Greely, Marcus Baker, Willis, Bartlett, Merriam, Ward, Henshaw and Abbe.

Fifth Regular Meeting, April 13, 1888.—Held in the Assembly Hall of the Cosmos Club, vice-president Merriam in the chair.

The discussion of the proposed Physical Atlas of the United States was continued, and was participated in by Messrs. Marcus Baker, Greely, Willis, Cosmos Mindeleff, Gilbert Thompson, Kenaston, Gannett and Van Deman.

Paper: The Survey of the Coast, by Mr. Herbert G. Ogden.—(*Published in Vol.* 1, *No.* 1, "*National Geographic Magazine.*")

Sixth Regular Meeting, April 27, 1888.—Held in the Assembly Hall of the Cosmos Club, the president, Mr. Hubbard, in the chair.

Papers: The Great Storm of March 11–14, 1888, by Gen. A. W. Greely and Mr. Everett Hayden.—(*Published in Vol.* 1, *No.* 1, "*National Geographic Magazine.*")

Geographic Methods in Geologic Investigation, by Prof. W. M. Davis.—(*Published in Vol.* 1, *No.* 1, "*National Geographic Magazine.*")

Seventh Regular Meeting, May 11, 1888.—Held in the Assembly Hall of the Cosmos Club, vice-president Merriam in the chair.

Papers: The Survey and Map of Massachusetts, by Mr. Henry Gannett.—(*Published in Vol.* 1, *No.* 1, "*National Geographic Magazine.*")

Graphic Triangulation, by Mr. W. D. Johnson.

Eighth Regular Meeting, May 25, 1888.—Held in the Assembly Hall of the Cosmos Club, vice-president Merriam in the chair.

Papers: The Classification of Geographic Forms by Genesis, by Mr. W. J. McGee.—(*Published in Vol.* 1, *No.* 1, "*National Geographic Magazine.*")

The Classification of Topographic Forms, by Mr. G. K. Gilbert.

The North Winds of California, by Mr. Gilbert Thompson.

NATIONAL GEOGRAPHIC SOCIETY.

CERTIFICATE OF INCORPORATION.

This is to Certify that we whose names are hereunto subscribed, citizens of the United States, and a majority of whom are citizens of the District of Columbia, have associated ourselves together pursuant to the provisions of the Revised Statutes of the United States relating to the District of Columbia, and of an act of Congress entitled: "An Act to amend the Revised Statutes of the United States relating to the District of Columbia and for other purposes," approved April 23, 1884, as a Society and body corporate, to be known by the corporate name of the National Geographic Society, and to continue for the term of one hundred years.

The particular objects and business of this Society are: to increase and diffuse geographic knowledge; to publish the transactions of the Society; to publish a periodical magazine, and other works relating to the science of geography; to dispose of such publications by sale or otherwise; and to acquire a library, under the restrictions and regulations to be established in its By-Laws.

The affairs, funds and property of the corporation shall be in the general charge of Managers, whose number for the first year shall be seventeen, consisting of a President, five Vice Presidents, a Recording Secretary, a Corresponding Secretary, a Treasurer and eight other members, styled Managers, all of whom shall be chosen by ballot at the annual meeting. The duties of these officers and of other officers and standing committees, and their terms and the manner of their election or appointment shall be provided for in the By-Laws.

Gardiner G. Hubbard.
C. E. Dutton.
O. H. Tittmann.
J. Howard Gore.
C. Hart Merriam.
J. R. Bartlett.
Rogers Birnie, Jr.
J. W. Powell.
Henry Gannett.
A. H. Thompson.
A. W. Greely.
Henry Mitchell.
George Kennan.
Marcus Baker.
Gilbert Thompson.

BY-LAWS.

ARTICLE I.

NAME.

The name of this Society is the "NATIONAL GEOGRAPHIC SOCIETY."

ARTICLE II.

OBJECT.

The object of this Society is the increase and diffusion of geographic knowledge.

ARTICLE III.

MEMBERSHIP.

The members of this Society shall be persons who are interested in geographic science. There may be three classes of members, active, corresponding and honorary.

Active members only shall be members of the corporation, shall be entitled to vote and may hold office.

Persons residing at a distance from the District of Columbia may become corresponding members of the Society. They may attend its meetings, take part in its proceedings and contribute to its publications.

Persons who have attained eminence by the promotion of geographic science may become honorary members.

Corresponding members may be transferred to active membership, and, conversely, active members may be transferred to corresponding membership by the Board of Managers.

The election of members shall be entrusted to the Board of Managers. Nominations for membership shall be signed by three active members of the Society; shall state the qualifications of the candidate; and shall be presented to the Recording Secretary. No nomination shall receive action by the Board of Managers until it has been before it at least two weeks, and no candidate shall be elected unless he receives at least nine affirmative votes.

ARTICLE IV.

OFFICERS.

The Officers of the Society shall be a President, five Vice Presidents, a Treasurer, a Recording Secretary and a Corresponding Secretary.

The above mentioned officers, together with eight other members of the Society, known as Managers, shall constitute a Board of Managers.

Officers and Managers shall be elected annually, by ballot, a majority of the votes cast being necessary to an election; they shall hold office until their successors are elected; and shall have power to fill vacancies occurring during the year.

The President, or, in his absence, one of the Vice Presidents, shall preside at the meetings of the Society and of the Board of Managers; he shall, together with the Recording Secretary, sign all written contracts and obligations of the Society, and attest its corporate seal; he shall deliver an annual address to the Society.

Each Vice President shall represent in the Society and in the Board of Managers, a department of geographic science, as follows;

Geography of the Land,
Geography of the Sea,
Geography of the Air,
Geography of Life,
Geographic Art.

The Vice Presidents shall foster their respective departments within the Society; they shall present annually to the Society summaries of the work done throughout the world in their several departments.

They shall be elected to their respective departments by the Society.

The Vice Presidents, together with the two Secretaries, shall constitute a committee of the Board of Managers on Communications and Publications.

The Treasurer shall have charge of the funds of the Society, shall collect the dues, and shall disburse under the direction of the Board of Managers; he shall make an annual report; and his accounts shall be audited annually by a committee of the Society and at such other times as the Board of Managers may direct.

The Secretaries shall record the proceedings of the Society and of the Board of Managers; shall conduct the correspondence of the Society; and shall make an annual report.

The Board of Managers shall transact all the business of the Society, except such as may be presented at the annual meeting. It shall formulate rules for the conduct of its business. Nine members of the Board of Managers shall constitute a quorum.

ARTICLE V.

DUES.

The annual dues of active members shall be five dollars, payable during the month of January, or, in the case of new members, within thirty days after election.

Annual dues may be commuted and life membership acquired by the payment of fifty dollars.

No member in arrears shall vote at the annual meeting, and the names of members two years in arrears shall be dropped from the roll of membership.

ARTICLE VI.

MEETINGS.

Regular meetings of the Society shall be held on alternate Fridays, from October until May, inclusive, and, excepting the annual meeting, shall be devoted to communications. The three regular meetings next preceding the annual meeting shall be devoted to the President's annual address and the reports of the Vice Presidents.

The annual meeting for the election of officers shall be the last regular meeting in December.

A quorum for the transaction of business shall consist of twenty-five active members.

Special meetings may be called by the President.

ARTICLE VII.

AMENDMENTS.

These by-laws may be amended by a two-thirds vote of the members present at a regular meeting, provided that notice of the proposed amendment has been given in writing at a regular meeting at least four weeks previously.

OFFICERS.

1888.

President.

GARDINER G. HUBBARD.

Vice Presidents.

HERBERT G. OGDEN.
J. R. BARTLETT.
A. W. GREELY.
C. HART MERRIAM.
A. H. THOMPSON.

Treasurer.

CHARLES J. BELL.

Secretaries.

HENRY GANNETT.
GEORGE KENNAN.

Managers.

CLEVELAND ABBE.
MARCUS BAKER.
ROGERS BIRNIE, JR.
G. BROWN GOODE.
WILLARD D. JOHNSON.
HENRY MITCHELL.
W. B. POWELL.
JAMES C. WELLING.

MEMBERS OF THE SOCIETY.

a., original members.
l., life members.
In cases where no city is given in the address, Washington, D. C., is to be understood.

Cleveland Abbe, *a. l.*,	U. S. Signal Office.
S. T. Abert,	725 20th st.
Jeremiah Ahern,	U. S. Geological Survey.
J. A. Allen,	Am. Museum of Nat. Hist., New York.
Clifford Arrick, *a.*,	U. S. Geol. Survey.
Miss E. L. Atkinson,	918 Mass. ave.
W. R. Atkinson, *a.*,	U. S. Geol. Survey.
Miss S. C. Ayres, *a.*,	U. S. Coast and Geodetic Survey.
Frank Baker, *a.*,	1315 Corcoran st.
Marcus Baker, *a.*,	U. S. Geol. Survey.
H. L. Baldwin, *a.*,	" "
E. C. Barnard, *a.*,	" "
J. R. Bartlett, *a.*,	Navy Department.
C. C. Bassett, *a.*,	U. S. Geol. Survey.
Lewis J. Battle,	" "
A. Graham Bell, *a.*,	1336 19th st.
Chas. J. Bell, *a.*,	1437 Penna. ave.
Julius Bien, *a.*,	New York City.
Morris Bien, *a.*,	U. S. Geol. Survey.
Rogers Birnie, Jr., *a.*,	War Department.
H. B. Blair, *a.*,	U. S. Geol. Survey.
J. H. Blodget, *a.*,	" "
S. H. Bodfish, *a.*,	" "
C. O. Boutelle, *a.*,	U. S. Coast and Geod. Survey.
Andrew Braid, *a.*,	" " "
L. D. Brent,	U. S. Geol. Survey.
H. G. Brewer, *a.*,	Hydrographic Office.
Wm. Brewster,	Cambridge, Mass.
Miss L. V. Brown,	1312 S st.
A. E. Burton, *a.*,	Boston, Mass.
Z. T. Carpenter, *a.*,	P. O. Box 387.
R. H. Chapman, *a.*,	U. S. Geol. Survey.
H. S. Chase, *a.*,	Navy Department.
T. M. Chatard, *a.*,	U. S. Geol. Survey.
A. H. Clark,	National Museum.

E. B. Clark, *a.*,	U. S. Geol. Survey.
Verplanck Colvin, *a.*,	Albany, N. Y.
E. E. Court,	Hydrographic Office.
R. D. Cummin, *a.*,	U. S. Geol. Survey.
W. E. Curtis, *a.*,	513 14th st.
Mrs. Caroline H. Dall, *a.*,	1603 O st.
C. C. Darwin, *a.*,	U. S. Geol. Survey.
Geo. Davidson, *a.*,	San Francisco, Cal.
Arthur P. Davis, *a.*,	U. S. Geol. Survey.
Mrs. A. P. Davis,	
Wm. M. Davis,	Philadelphia, Pa.
W. H. Dennis, *a.*,	U. S. Coast and Geod. Survey.
J. S. Diller, *a.*,	U. S. Geol. Survey.
E. M. Douglas, *a.*,	" "
B. W. Duke, *a.*,	" "
A. F. Dunnington, *a.*,	" "
A. H. Dutton, *a.*,	Hydrographic Office.
C. E. Dutton, *a.*,	U. S. Geol. Survey.
G. L. Dyer,	Navy Department.
G. W. Dyer, *a.*,	1003 F st.
J. R. Edson, *a.*,	1003 F st.
W. P. Elliott, *a.*,	Navy Department.
George A. Fairfield, *a.*,	U. S. Coast and Geod. Survey.
Walter Fairfield, *a.*,	" " "
B. Fernow, *a.*,	Dept. of Agriculture.
J. P. Finley, *a.*,	U. S. Signal Office.
E. G. Fischer, *a.*,	U. S. Coast and Geod. Survey.
C. H. Fitch, *a.*,	U. S. Geol. Survey.
L. C. Fletcher, *a.*,	" "
Robert Fletcher, *a.*,	Army Medical Museum.
W. C. Ford, *a.*,	State Department.
Gerard Fowke, *a.*,	Bureau of Ethnology.
N. P. Gage, *a.*,	Seaton School.
Henry Gannett, *a.*,	U. S. Geol. Survey.
S. S. Gannett, *a.*,	" "
G. K. Gilbert, *a.*,	" "
D. C. Gilman, *a.*,	Johns Hopkins Univ., Baltimore, Md.
G. Brown Goode, *a.*,	National Museum.
R. U. Goode, *a.*,	U. S. Geol. Survey.
Edward Goodfellow, *a.*,	U. S. Coast and Geod. Survey.
R. O. Gordon, *a.*,	U. S. Geol. Survey.
F. D. Granger,	U. S. Coast and Geod. Survey.
A. W. Greely, *a.*,	U. S. Signal Office.
Morris M. Green,	Dept. of Agriculture.
W. T. Griswold, *a.*,	U. S. Geol. Survey.
F. P. Gulliver,	" "
Merrill Hackett, *a.*,	" "
Dabney C. Harrison, *a.*,	" "
E. M. Hasbrouck,	" "

E. E. Haskell, *a.*,	U. S. Coast and Geod. Survey.
Everett Hayden, *a.*,	Navy Department.
A. J. Henry, *a.*,	U. S. Signal Office.
H. W. Henshaw, *a.*,	Bureau of Ethnology.
Gustave Herrle, *a.*,	Hydrographic Office.
W. H. Herron, *a.*,	U. S. Geol. Survey.
George A. Hill, *a.*,	U. S. Signal Office.
W. F. Hillebrand, *a.*,	U. S. Geol. Survey.
H. L. Hodgkins, *a.*,	Columbian University.
C. L. Hopkins,	Dept. of Agriculture.
D. J. Howell, *a.*,	1003 F st.
E. E. Howell, *a.*,	Rochester, N. Y.
W. T. Hornaday, *a.*,	National Museum.
Gardiner G. Hubbard, *a.*,	1328 Connecticut ave.
C. T. Iardella, *a.*,	U. S. Coast and Geod. Survey.
J. H. Jennings, *a.*,	U. S. Geol. Survey.
A. B. Johnson, *a.*,	Light House Board.
S. P. Johnson,	Le Droit Park.
W. D. Johnson, *a.*,	U. S. Geol. Survey.
Anton Karl, *a.*,	" "
S. H. Kaufmann, *a.*,	1000 M st.
C. A. Kenaston, *a.*,	Howard University.
George Kennan, *a.*,	1318 Massachusetts ave.
Mark B. Kerr, *a.*,	U. S. Geol. Survey.
E. F. Kimball,	Le Droit Park.
S. I. Kimball, *a.*,	" "
Harry King, *a.*,	U. S. Geol. Survey.
F. J. Knight, *a.*,	" "
F. H. Knowlton, *a.*,	" "
Peter Koch, *a.*,	Bozeman, Mont.
Wm. Kramer,	U. S. Geol. Survey.
W. E. Lackland, *a.*,	" "
Boynton Leach,	Hydrographic Office.
R. L. Lerch, *a.*,	" "
A. Lindenkohl, *a.*,	U. S. Coast and Geod. Survey.
H. Lindenkohl, *a.*,	" " "
R. L. Longstreet, *a.*,	U. S. Geol. Survey.
W. H. Lovell,	" "
James A. Maher, *a.*,	" "
Van H. Manning, Jr., *a.*,	" "
Henry L. Marindin,	U. S. Coast and Geod. Survey.
C. C. Marsh, *a.*,	Navy Department.
Washington Matthews, *a.*,	Army Med. Museum.
W. J. McGee, *a.*,	U. S. Geol. Survey.
R. H. McKee, *a.*,	" "
R. C. McKinney, *a.*,	" "
George Melville, *a.*,	Navy Department.
A. G. Menocal, *a.*,	" "
C. Hart Merriam, *a.*,	Dept. of Agriculture.

Cosmos Mindeleff,	Bureau of Ethnology.
Victor Mindeleff,	" "
Henry Mitchell, *a.*,	Nantucket, Mass.
A. T. Mosman, *a.*,	U. S. Coast and Geod. Survey.
Robert Muldrow, *a.*,	U. S. Geol. Survey.
A. E. Murlin,	" "
Miss J. C. Myers,	804 11th st.
E. W. F. Natter,	U. S. Geol. Survey.
Louis Nell, *a.*,	" "
Charles Nordhoff, *a.*,	" "
Herbert G. Ogden, *a.*,	U. S. Coast and Geod. Survey.
T. S. O'Leary, *a.*,	Hydrographic Office.
F. H. Parsons, *a.*,	U. S. Coast and Geod. Survey.
W. W. Patton, *a.*,	Howard University.
A. C. Peale, *a.*,	U. S. Geol. Survey.
E. T. Perkins, Jr., *a.*,	" "
G. H. Peters, *a.*,	Navy Department.
W. J. Peters, *a.*,	U. S. Geol. Survey.
J. W. Powell, *a.*,	" "
W. B. Powell, *a.*,	Franklin School.
D. W. Prentiss, *a.*,	1101 14th st.
J. H. Renshawe, *a.*,	U. S. Geol. Survey.
Eugene Ricksecker, *a.*,	Portland, Oreg.
C. V. Riley, *a.*,	Dept. of Agriculture.
Homer P. Ritter, *a.*,	U. S. Coast and Geod. Survey.
A. C. Roberts, *a.*,	Hydrographic Office.
I. C. Russell, *a.*,	U. S. Geol. Survey.
C. S. Sargent, *a.*,	Brookline, Mass.
W. S. Schley, *a.*,	Navy Department.
S. H. Scudder, *a.*,	Cambridge, Mass.
N. S. Shaler, *a.*,	" "
John S. Siebert,	Hydrographic Office.
Edwin Smith, *a.*,	U. S. Coast and Geod. Survey.
Middleton Smith, *a.*,	1616 19th st.
E. J. Sommer, *a.*,	U. S. Coast and Geod. Survey.
Leonhard Stejneger, *a.*,	National Museum.
*James Stevenson, *a.*,	U. S. Geol. Survey.
Chas. H. Stockton, *a.*,	Navy Department.
Frank Sutton,	U. S. Geol. Survey.
Mary C. Thomas, *a.*,	U. S. Coast and Geod. Survey.
A. H. Thompson, *a.*,	U. S. Geol. Survey.
Gilbert Thompson, *a.*,	" "
Laurence Thompson, *a.*,	Denver, Colorado.
R. E. Thompson,	War Department.
O. H. Tittmann, *a.*,	U. S. Coast and Geod. Survey.
R. M. Towson, *a.*,	U. S. Geol. Survey.
W. L. Trenholm, *a.*,	Treasury Dept.

* Deceased.

Frank Tweedy, *a.*,	U. S. Geol. Survey.
Chas. F. Urquhart, *a.*,	" "
H. C. Van Deman,	Dept. of Agriculture.
George Vasey, *a.*,	" "
W. I. Vinal, *a.*,	U. S. Coast and Geod. Survey.
A. Von Haake.	Post Office Dept.
C. D. Walcott, *a.*,	U. S. Geol. Survey.
H. S. Wallace, *a.*,	" "
Lester F. Ward, *a.*,	" "
W. H. Weed, *a.*,	" "
J. B. Weir, *a.*,	U. S. Coast and Geod. Survey.
J. C. Welling, *a.*,	Columbian University.
C. A. White, *a.*,	U. S. Geol. Survey.
C. H. White,	Navy Department.
J. T. Wilder, *a. l.*,	Roan Mt., Tenn.
Miss Mary Wilder.	" "
Bailey Willis, *a.*,	U. S. Geol. Survey.
Mrs. Bailey Willis,	
A. E. Wilson,	U. S. Geol. Survey.
H. M. Wilson, *a.*,	" "
Thos. Wilson,	National Museum.
Isaac Winston,	U. S. Coast and Geod. Survey.
R. S. Woodward, *a.*,	U. S. Geol. Survey.
H. C. Yarrow, *a.*,	Army Medical Museum.
Chas. M. Yeates, *a.*,	U. S. Geol. Survey.

Vol. I. No. 2.

THE

NATIONAL GEOGRAPHIC MAGAZINE.

PUBLISHED BY THE

NATIONAL GEOGRAPHIC SOCIETY.

WASHINGTON, D. C.

Price 50 cents.

CONTENTS.

April, 1889,

PRESS OF TUTTLE, MOREHOUSE & TAYLOR, NEW HAVEN, CONN.

THE

NATIONAL GEOGRAPHIC MAGAZINE.

Vol. I. 1889. No. 2.

AFRICA, ITS PAST AND FUTURE.

Africa, the oldest of the continents, containing the earliest remains of man, and the birthplace of European civilization, is the last to be explored. Long before the temples of India or the palaces of Nineveh were built, before the hanging garden of Babylon was planted, the pyramids of Cheops and Cephren had been constructed, the temples of Palmyra and Thebes filled with worshipers.

Greece owes its civilization to Egypt: its beautiful orders of architecture came from the land of the Nile. The civilization of Egypt had grown old, and was in its decay, when Rome was born. Think what a vast abyss of time separates us from the days of Romulus and Remus! And yet the pyramids of Egypt were then older by a thousand years than all the centuries that have passed since then.

For ages upon ages, Africa has refused to reveal its secrets to civilized man, and, though explorers have penetrated it from every side, it remains to-day the dark continent. This isolation of Africa is due to its position and formation. It is a vast, ill-formed triangle, with few good harbors, without navigable rivers for ocean-vessels, lying mainly in the torrid zone. A fringe of low scorched land, reeking with malaria, extends in unbroken monotony all along the coast, threatening death to the adventurous explorer. Our ignorance of Africa is not in consequence of its situation under the equator, for South America in the torrid zone has long been known. There the explorer easily penetrates its recesses on its great rivers,—the Orinoco, Amazon, and La Plata,—for they are navigable from the ocean far into the interior. The Amazon, 3,000 miles from its mouth, is only 210 feet above the ocean-level, and, with its branches, is navigable for 10,000 miles. Africa also has three great rivers,—one on each side of this peninsula. On the north, the Nile, the river of the past, empties into the Mediterranean Sea, but its navigation is soon interrupted by five cataracts ; so that the camel, the ship of the desert, bears the wares of Europe from the foot of the first cataract far up the river, 800 miles, to Berber, whence they are again shipped by boat 2,000 miles to Gondokoro, close to the lakes Albert and Victoria Nyanza, 4,000 feet above the sea-level, 4,200 miles by water from the Mediterranean.

On the west, the Kongo, the river of the future, empties into the Atlantic Ocean under the equatorial sun ; but its navigation is also impeded by successive falls extending from its mouth to Stanley Pool. Then there is almost uninterrupted navigation on the river and its tributaries for 10,000 miles. Far inland the head waters of its north-eastern branches interlace with the waters of the Nile. Another branch rises in Lake Tanganyika in eastern Africa, while the main river finds its source higher up in the mountains, north of Lake Nyassa, 5,000 feet above the sea-level. On the east the Zambezi, the great river of southern Africa, empties into the Indian Ocean opposite Madagascar. The navigation of its main branch, the Shire, is interrupted not far from the ocean. The Zambezi itself is navigable to the rapids near Tete, 260 miles from its mouth ; while one or two hundred miles higher up are the mighty falls of Victoria, only exceeded in volume of water by the Niagara, and nearly equal in height.

In whatever direction Europeans attempted to penetrate Africa, they were met by insurmountable obstacles. Communication by water was prevented by falls near the mouths of great rivers. The greater part of the coast was very unhealthy, and, where not unhealthy, a desert was behind it ; but these obstacles, which formerly prevented exploration, now stimulate the traveler. The modern explorations of Africa commenced one hundred years ago, when Mungo Park crossed the Desert of Sahara, and lost his life in descending the Niger. From that time to the present, travelers in ever-increasing numbers have entered Africa from every side. Some who have entered from the Atlantic or Pacific coasts have been lost in its wilds, and two or three years after have emerged on the opposite coast; others have passed from the coast, and have never been heard from. Zanzibar has been a favorite starting-point for the lake region of Central Africa. Stanley started from Zanzibar on his search for Livingstone with two white men, but returned alone. Cameron set out by the same path with two companions, but, upon reaching the lake region, he was alone. Keith Johnson, two or three years ago, started with two Europeans: within a couple of months he was gone. Probably every second man, stricken down by fever or accident, has left his bones to bleach along the road. Drummond, a recent explorer of Africa, chose a route by the Zambezi and Shire Rivers as healthier and more desirable. Let us hear his experience. Early in his journey, at the missionary station of Livingstonia, on Lake Nyanza, he entered a missionary home: it was spotlessly clean; English furniture in the room, books lying about, dishes in the cupboards; but no missionary. He went to the next house: it was the school; the benches and books were there, but neither scholars nor teacher. Next, to the blacksmith shop: there were the tools and anvil, but no blacksmith. And so on to the next and the next, all in perfect order, but all empty. A little way off, among the mimosa groves, under a huge granite mountain, were graves: there were the missionaries.

The Niger is the only river in all Africa navigable by small steamers from the ocean; but the Niger does not give access to the interior, as it rises within 100 miles of the ocean, and, after making a great bend around the mountains of the Guinea coast, empties into the ocean only about five degrees south of its source, after a course of 2,500 miles. Its main branch, the Benue (or "Mother of Waters"), is navigable 500 or 600 miles above its junction with the Niger. The country through which it flows is thickly peopled and well cultivated; but the natives are fierce and warlike, and have until recently prevented any exploration of the Benue.

The Mountains of Africa.

As mountain-ranges determine the course of rivers, influence the rainfall, and temper the climate, we must understand the mountain system of Africa before we can understand the continent as a whole.

Standing on the citadel at Cairo, and looking south, you see a sandstone ridge which gradually grows in altitude and width of base as it runs far away to the south, even to the Cape of Good Hope at the other end of Africa. Successive ranges of mountains follow the coast, sometimes near, at others two or three hundred miles inland; the land, in the latter case, ascending from the coast. The only breaks in this long chain are where the Zambezi and Limpopo force their way to the Indian Ocean.

In Abyssinia, on the Red Sea, there is a range of snowy mountains 14,700 feet in height. A few hundred miles to the southeast, and near Lake Victoria Nyanza, almost under the equator, is another snow-capped mountain, Kilima Njaro, 18,700 feet high,—the highest mountain in Africa,—and the mountains of Massai-Land, a continuation of the Abyssinian Mountains. Another range, apparently an offshoot of the long range from the Red Sea, forms a wall 100 miles long, and 10,000 feet high, on the east of Lake Nyassa, separating the waters of that lake from the Indian Ocean. This range continues to the Zambezi. South of this river the mountains rise 8,000 to 10,000 feet in height. In Cape Colony are several ranges of mountains. The highest peak is Compas Berg, 8,500 feet. In the eastern center of Africa, in the equatorial region, is an elevated plateau in which is the lake region, then there is a sudden rise, and a gradual descent towards the Atlantic. There are few continuous ranges of mountains on the western coast; but at Kamerun there is a cluster of mountains reaching an elevation of 13,100 feet; and south of Morocco some of the peaks of the Atlas Mountains reach an elevation of 12,000 to 13,000 feet, but they have little if any influence on the rainfall or temperature of the country. It will be seen from this statement that eastern Africa has high mountain-ranges rising into an elevated plateau; that the land in Equatorial Africa gradually descends toward the west and north-west until within one or two hundred miles of the Atlantic Ocean, when the descent is rapid to the low and unhealthy coast-lands. Through equatorial Africa runs the Kongo, the land north of the Kongo gradually rising to an elevation of about 2,000 feet, and then descending to 1,200 feet at Lake Chad. South of the Kongo the land rises to an elevation of 3,000 feet, and retains this elevation far south into the Portuguese territory.

Careful computations have been made to ascertain the average elevation of the continent. The mean of the most careful estimates is a little over 2,000 feet. The interior is therefore elevated above the miasmatic influences of the coast, but exactly what effect this elevation has upon the temperature can only be ascertained after careful investigation and a series of observations. North of Guinea and Senegambia the coast is less unhealthy; but, as the Desert of Sahara extends to the ocean, the country is of little value, and is therefore left to the native tribes, unclaimed by Europeans.

In the International Scientific Series it is stated that there are in Africa ten active volcanoes,—four on the west coast, and six on the east,—but I have not found any corroboration of this report, and think it very doubtful if there are any volcanoes now in eruption. The Kilima Njaro and Kamerun were formerly active volcanoes, for the craters still exist. In the south the diamond-fields are of volcanic ash formation.

Equatorial Africa.

The lake region of Africa stretches from the head waters of the upper Nile three degrees south, to the waters of the Zambezi, fifteen degrees south,—a lake region unequalled, in extent and volume of water, except by our lakes. Here is the Victoria Nyanza, the queen of inland seas, 4,000 feet above the sea-level; and a long series of lakes, great and small, at equal elevation. The more striking are Bangweolo to the south-west, the grave of Livingstone, and Nyassa on the south-east. In their depths the Nile, the Kongo River, and the Shire (the main branch of the Zambezi) have their source.

The great belt of equatorial Africa, situated between the 15th parallel of north latitude and the 15th parallel of south latitude, has continuous rains, is everywhere well watered, and has a rich and fertile soil. Some portions are thickly populated, and it is capable of sustaining a dense population. North and south of this belt there are two other belts of nearly equal width. In each of these belts there are wet and dry seasons, with abundant rain for the crops. The heaviest rainfall in the north belt is in June, while in the south belt it is in December. The rainfall gradually grows less toward the north, and also toward the south, until it ceases in the Desert of Sahara on the north, and in the Desert of Kalahari on the south. On the edge of these deserts are Lake Chad on the north, and Lake Ngami on the south. North of the Desert of Sahara, and south of the Desert of Kalahari, there is an abundant rainfall, a healthy climate, and fertile soil. Morocco, Algiers, and Tripoli, on the Mediterranean, are in the north region; and Zulu-Land, the Orange Free State, and Cape Colony, in the corresponding region of the south.

That portion of Africa north of the equator is three or four times greater than that south, and the Sahara Desert and Lake Chad are several times greater than the Kalahari Desert and Lake Ngami. The Sahara Desert, the waterless ocean three times as large as the Mediterranean, extends from the Atlantic Ocean to the Red Sea, broken only by the narrow valley of the Nile. It is interspersed with oases, with the valleys of many dry streams, and with some mountains 8,000 feet. It has the hottest climate in the world. Travelers tell us, that, in upper Egypt and Nubia, eggs may be baked in the hot sands; that the soil is like fire, and the wind like a flame; that in other parts of the desert the sand on the rocks is sometimes heated to 200° in the day-time, while in the following night the thermometer falls below freezing-point. In crossing the desert the traveler will hardly need a guide, for the road is too clearly marked by the bones and skeletons that point the way.

Lake Chad receives the drainage of a considerable area of country. In the dry season it has no outlet, and is then about the size of Lake Erie. In the wet season it is said to be five times as large. Its level rises by twenty or thirty feet until it overflows into the Desert of Sahara, forming a stream which runs northward for several hundred miles, and is finally lost in a great depressed plain. In the southern part of Africa the level of Lake Ngami rises and falls in a similar manner.

Through the great equatorial belt runs the Kongo, one of the wonderful rivers of the world. The more we know of this river and its tributaries, the more we are impressed by its greatness and importance. Its principal source is in the mountain-range which separates Lake Nyassa from Lake Tanganyika, between 300 and 400 miles west of the Indian Ocean; thence it runs southerly through Lake Bangweolo. On leaving this lake, it takes a north-west course, running from 12° south latitude to 2° north latitude, thence running south-westerly to the ocean, nearly 3,000 miles. The river Sankuru, its principal tributary, empties into the Kongo some distance above Stanley Pool on the south. The mouths of the Sankuru were discovered by Stanley, who was struck by the size and beauty of the river, and by the lakes which probably connect it by a second outlet with the Kongo; but he little realized the magnitude of the river. Even before the journey of Stanley, Portuguese explorers had crossed several large streams far to the south of the Kongo,—the Kuango, the Kassai, and the Lomami,—and explored them for several hundred miles, but were unable to follow them to their mouths. In 1885 and 1886, Wissman and the Belgian explorers sailed up the Sankuru to the streams discovered by the Portuguese. The next largest branch is the Obangi, now called the Obangi-Welle, which flows into the Kongo on the westerly side of the continent, a little south of the equator. An expedition organized by the Kongo Free State steamed up this river in the winter of 1887 and 1888, and solved the problem so long discussed, of the outlet of the Welle. The expedition left the Kongo in the steamer "En Avant," October 26, 1887. It passed several rapids, and steamed to 21° 55′ east longitude, when it was stopped by the "En Avant" running on a rock, and the opposition of hostile natives. Here it was only 66 miles from the westernmost point on the Welle reached by Junker, and in the same latitude, each stream running in the same direction, leaving no room to doubt that the two waters unite.

The Little Kibali, which rises a little to the west of Wadelai in the mountains of Sudan, is the initial branch of this river, which bears successively the name of "Kibali" "Welle" and "Doru," and empties into the Kongo under the name of "Obangi," after a course of 1,500 miles.

The discharge of water from the Kongo is only a little less than that from the Amazon, and is said to be three times as great as the discharge from the Mississippi. Grenfel, the English missionary and traveler, says there is no part of the Kongo basin more than one hundred miles from navigable water. What the railroad does for America, the steamboat will do for the Kongo Free State on its seventy-two hundred miles of navigable water.

Appropriation of Africa by Europe.

The English, French, Germans, and Belgians have within a few years planted colonies in Africa. They believe it is more for their interest to colonize Africa than to permit their surplus population to emigrate to America. These countries realize the necessity of creating new markets, if they are to continue to advance. In Africa the colonies must depend upon the home country, and open new fields for manufactures and commerce. They know that in equatorial Africa there are more than 100,000,000 people wanting every thing, even clothes.

The whole coast of Africa on the Mediterranean Sea, the Atlantic and Indian Oceans from the Red Sea to the Isthmus of Suez, is claimed by European nations, with the exception of two or three small inhospitable and barren strips of coast. England occupies Egypt, and will hold it for an indefinite period. France has its colonies in Tripoli, Algiers, and Morocco, and on the Atlantic coast its factories in Senegambia. It seeks a route from Algiers across the desert to Lake Chad, and from Senegambia up the Senegal by steamer, thence across the country by rail to the head of navigation on the Niger, and down that river to Timbuctu.

England occupies Sierra Leone, the Gold and Slave Coasts, the delta and valley of the Niger, and its branch the Benue. It has factories on these rivers, and small steamers plying on them, and seeks Timbuctu by the river Niger. It controls almost the entire region where the palm-oil is produced.

Timbuctu, long before Africa was known to Europe, was the centre of a large trade in European and Asiatic goods. Caravans crossed the Desert of Sahara from Timbuctu north to the Mediterranean, and east to Gondokoro, carrying out slaves, gold and ivory and bringing back European and Asiatic goods.

Sandwiched between the English possessions, Liberia struggles for existence, its inhabitants fast degenerating into barbarism.

Joining the English possessions on the Gold Coast, two degrees north of the equator, are the German possessions of Kamerun, with high mountains and invigorating breezes ; but the land at the foot is no more favorable to the European than the Guinea coast. One or two hundred miles in the interior of this part of the continent, the land rapidly rises to the tableland of equatorial Africa, rich and fertile, resembling the valley of the Kongo, possibly habitable by Europeans.

Next, the French occupy the Ogowe, its branches, and the coast, to the Kongo, and claim the country inland to the possessions of the Kongo Free State. Under M. Brazza, they have thoroughly explored the country to the river Kongo, and have established factories at Franceville and other places.

The Kongo Free State comes next. It holds on the coast only the mouth of the river, its main possessions lying in the interior, Belgium is the only country that has planted colonies inland. Like all the interior of equatorial Africa, the valley of the Kongo is well watered and has continuous rains. The land is rich and fertile, but is practically inaccessible, and, before any extensive commerce can be carried on, must be connected by railroad with the ocean. The Compagnie du Congo has just completed a survey for a railroad on the south side of the Kongo, from Matadi, opposite Vivi, to Stanley Pool. It did not encounter any unusual difficulties, and has submitted the plans and projects to the King of Belgium for his approval.

South of the Kongo Free State are the Portugese possessions of Angola, Benguela, and Mossamedes. Portugal, the first country to circumnavigate Africa, and the first to colonize it, has for several centuries had factories, and carried on a large trade with Africa, exchanging clothes and blankets for slaves, gold and ivory. It claimed the valley of the Kongo; but the claim has been reduced, and is now bounded for a considerable distance on the north by a line running due east and west on the 6th parallel of south latitude. They have good harbors at St. Paul de Loango, Benguela, and Mossamedes, on the Atlantic coast, and the best harbor of Africa, at Delagoa Bay on the Indian Ocean. The territory claimed will, I believe, prove to be the most valuable in Africa. It is well watered by numerous tributaries of the Kongo and by the Zambezi and its branches. It is higher than the Kongo valley, and is therefore more healthy. Several Portuguese, English, and German travelers have crossed and recrossed this part of the continent, and the Portuguese have some small settlements on the coast and in the interior. The Portuguese of the present generation have not the enterprise and trading spirit of their forefathers, and are doing very little for the settlement of the country.

South of the Portuguese possessions, England claims from the Portuguese possessions on the Atlantic to their possessions on the Pacific, including Namaqua-Land, Cape Colony, the Transvaal, and Zulu-Land.

Namaqua and Damara Land, formerly claimed by the Germans, are now put down on some of the maps as belonging to England. The only harbor on the coast is held by the English; and, from the character of the country, we are not surprised that the Germans have abandoned it, for we are told that "the coast is sandy and waterless, deficient in good harbors, devoid of permanent rivers, washed by never-ceasing surf, bristling with reefs, and overhung by a perpetual haze."

North of Zulu-Land, the Portuguese claim the coast to Zanzibar. Over Zanzibar, Germany has lately assumed the protectorate, under a treaty with the Sultan of the country, claiming the land from the ocean to the great lakes; then England again, a little to the north and far to the west of Zanzibar, the rival of Germany in its claims. The English have factories west of Zanzibar, and a regular route up the Zambezi and Shire Rivers, with a single portage to Lake Nyassa, and a road to Lake Tanganyika. They have steamers on each of the lakes, and several missionary and trading stations. The latest news from this part of Africa says the route to the lakes has been closed, and the missionaries and merchants murdered.

North of the English possessions, the coast to the Red Sea is barren and inhospitable: it has little rain and no harbors, and is so worthless that it has not been claimed by any European nation. North of this region is Abyssinia on the Indian Ocean and Red Sea,—a mountainous country with deep valleys, rich and fertile, but very unhealthy. Three or four thousand feet above the level of the sea, is a healthier country, inhabited by a race of rugged mountaineers, whom it has been impossible to dispossess of their lands. North of Abyssinia, on the Red Sea, Italy has a small colony at Massaua, and England a camp at Suakin. The only parts of the coast not claimed by Europeans are inhospitable, without population or cultivation of any kind.

The Belgians have spent many millions in the exploration of the Kongo and its tributaries. They have eighteen small steamers making trips from Leopoldville up the river to Stanley Falls, and up its branches, supplying the main stations in the basin of the Kongo. The Kongo Free State, unlike all other African colonies, is free to all. Merchants of any nation can establish factories, carry on trade, and enjoy the same privileges and equal facilities with the Belgians. The valley of the Kongo, and the plateau of the great lakes, have a similar climate and soil; but the Kongo is easier of access, provisions are cheaper, more readily obtained, and the natives are less warlike. The Kongo Free State will therefore be more rapidly settled than any other part of Africa excepting Cape Colony.

The trade with these countries is carried on by European companies under royal charter, with quasi-sovereign powers for ruling the country and governing the natives, as well as for trading with them. England, Germany, and Portugal subsidize steamship companies which make regular trips along the western coast, stopping at the different stations.

From this statement it will be seen that England occupies the healthiest portion of Africa (Cape Colony), the most fertile valleys (the Nile and the Niger), the richest gold-fields (Gold Coast and Transvaal) ; that Portugal comes next, claiming the most desirable portion of equatorial Africa north of Cape Colony and south of the Kongo, but that it is unable to colonize this country, which will inevitably fall under the control of England ; that the French claim Algiers and Senegambia, and are contending with England for the trade of Timbuctu and the upper valley of the Niger ; that Germany, after vain attempts to penetrate the interior from Kamerun and Angra Pequena, has planted her flag at Zanzibar, and has determined to contest with England the lake region and the great plateaus of Central Africa ; while Italy, imitating the other states, tries in vain to obtain a footing on the Red Sea, worthless if obtained.

Population.

The population of Africa is roughly estimated at 200,000,000, —about 18 to a square mile, as against 88 in Europe. It is supposed that Africa was originally inhabited by the Hottentots, or Bushmen, who are now found only in south-western Africa, and by the Pygmies or Dwarfs scattered about Central Africa, who, some say, belong to the same group. This group is noted for its dwarfed stature, generally under five feet ; but whether their size is natural, or due to privation and scanty food, is not certainly known. The Hottentot language is distinct from any other known form of speech. The Bantu occupy the greater part of Africa south of the equator. They probably formerly inhabited north-eastern Africa, but were driven from their homes by the Hamites. The Bantu resemble the Negro in their general character, color, and physique, but their language shows essential differences. There are countless tribes of Bantu, each tribe having its own language, yet there was originally a primeval Bantu mother-tongue, from which all the dialects of this immense region are undoubtedly derived. The idioms of this family are generally known as the alliteral class of languages. North of the Bantu are the Negroes proper, occupying the greater part of Africa between 5° and 15° north latitude. The negro tribes are multitudinous, and, though alike in their main physical features, are diverse in their speech.

North of the Negro are the Nuba Fulah group, apparently indigenous to Africa, but without any thing in common with the other indigenous groups. Their name, "Pullo," or "Fulah," means "yellow," and their color serves to distinguish them from the Negro. The Hottentot, Bantu, Negro, and Fulah, though distinct, have each of them the agglutinative forms of speech. The Hamites are found along the valley of the Nile, in Abyssinia, and portions of the Sudan. The Shemitic tribes occupy the larger part of the Sudan, bounded on the east by the Nile, and on the north by the Mediterranean and North Atlantic.

About one-half of the population are Negroes proper, one-fourth Bantu, one-fourth Shemites and Hamites, a few Nuba Fulahs and Hottentots. The Negroes and Bantu are Pagans; the Shemites and Hamites, Mohammedans. There are, almost, innumerable tribes, speaking different languages or different dialects. Over six hundred tribes and languages have been classified by Shilo, yet each is generally unintelligible to the other. Practically speaking, there are but two great divisions,—the Negroes and Bantu, occupying equatorial and southern Africa; and the Hamites and Shemites, northern Africa. But there is no clear-cut line even between the Mohammedan and Negro. For many hundred years the Negroes have been taken as slaves, and carried into the north of Africa, and have furnished the harems with wives, and the families with servants. The servants are often adopted into the families, so that the Negro blood now largely predominates even among the Shemites and Hamites.

A broader and more practical distinction than that of language or blood is made by the religion of the African. The Mohammedan religion was probably brought from Arabia by the Shemites. They conquered the country along the coast, and exterminated or pushed to the south the former inhabitants. Then, more slowly but steadily, Mohammedanism forced its way south by the sword or by proselyting. Within the last thirty years it has re-assumed its proselyting character, and is now more rapidly extending than at any previous time.

Its missionaries are of a race nearly allied to the Negro. They live among them, adopting their customs, and often intermarrying with them. They teach of one God, whom all must worship and obey, and of a future life whose rewards the Negro can comprehend. They forbid the sacrifice of human victims to appease the wrath of an offended deity. They forbid drunkenness. They give freedom to the slave who becomes a Moslem, and thus elevate and civilize those among whom they dwell. The Christian missionary is of a race too far above him. He is a white man, his lord and master. He teaches of things his mind cannot reach, of a future of which he can form no conception ; he brings a faith too spiritual ; he labors with earnestness and devotion, even to the laying-down of his life. Yet the fact remains that Christianity has produced but little impression in civilizing and elevating the people, while the influence of Mohommedanism is spreading on every side.

In passing from the equator south, the tribes become more degraded. Sir Henry Maine enunciated the theory of the evolution of civilization from the lowest state of the savage. In Africa he could have found all stages of civilization ; in the lowest scale, man and his mate, living entirely on the fruits of the earth, in a nude condition, his only house pieces of bark hung from the trees to protect him from the prevailing wind ; the vulture his guide to where, the previous night, the lion had fallen on his prey, leaving to him the great marrow-bones of the elephant or the giraffe ; his only arms a stick ; belonging to no tribe, with no connection with his fellow-men, his hand against every man, the family relation scarcely recognized. It is the land of the gorilla, and there seems to be little difference between the man and the ape, and both are hunted and shot by the Boers. In ascending the scale, the family and tribal relation appears,—a house built of cane and grass or the bark of the tree; a few flocks; skill in setting traps for game ; the weapon a round stone, bored through, and a pointed stick fastened in the hole. Then come tribes of a low order of civilization, that cultivate a little ground, having a despotic king, who has wives without limit, numbering in some cases, it is said, 3,000 ; wives and slaves slaughtered at his death, to keep him company and serve him in another life. With them, cannibalism is common. Then come tribes of a higher civilization, where the power of the chief is limited, where iron, copper, and gold are manufactured, and trade is carried on with foreigners, where fire-arms have been substituted for the bow and spear; next the Mohammedan; and last of all, on the shores of the Mediterranean, the civilization of the French and English.

It is a curious fact that many tribes that had made considerable advance in manufacturing iron and copper, have for some time ceased manufacturing; that others have retrograded, and have lost some of the arts they formerly possessed. This decline apparently took place after the Mohammedans had conquered North Africa, and sent their traders among the Negro tribes, who sold the few articles the Negro needed cheaper than they could manufacture them, and therefore compelled them to give up their own manufactures. Such was the effect of free trade on interior Africa. The Mohammedans also manufacture less than formerly, depending more and more upon European manufactures. The enterprise of the white race defies native competition, and stifles attempts at native manufactures: there is therefore among the natives a great falling-off in the progress of outward culture, and the last traces of home industries are rapidly disappearing.

Slave-Trade.

One of the departments of this society is the geography of life. At the head of all life stands man: it is therefore within our province to investigate those questions which more intimately concern and influence his welfare.

Slavery and the slave-trade have, within the last two hundred years, affected African life more than all other influences combined; and this trade, with all its sinister effects, instead of diminishing, is ever increasing. It has had a marked effect not only on the personal and tribal characters of the inhabitants, but on their social organization, and on the whole industrial and economic life of the country. It has not only utterly destroyed many tribes, but it has made the condition of the other tribes one of restless anarchy and insecurity. It has been the great curse of Africa, and for its existence the nations of Europe have been, and are, largely responsible. The temper and disposition of the Negro make him a most useful slave. He can endure continuous hard labor, live on little, has a cheerful disposition, and rarely rises against his master.

There are two kinds of slavery,—home and foreign. The first has always prevailed in Africa. Prisoners taken in war are sacrificed, eaten, or made slaves. Slavery is also a punishment for certain offences, while in some tribes men frequently sell themselves. These slaves are of the same race and civilization as their masters. They are usually well treated, regarded as members of the family, to whom a son or daughter may be given in marriage, the master often preferring to keep his daughter in the family to marrying her to a stranger. This slavery is a national institution of native growth. It is said one half of the inhabitants are slaves to the other half. The horrors of the slave-trade are unknown in this kind of slavery.

In the other case the slave is torn from his home, carried to people, countries, and climates with which he is unfamiliar, and to scenes and civilization which are uncongenial, where his master is of a different color and of another and higher civilization, where the master and slave have nothing in common. The Spaniards made slaves of the Indians of America, but they were incapable of work, unfitted for slavery, and rapidly faded away. In pity for the Indians, the Africans were brought to supply their places. Their ability to labor was proved, and they were soon in great demand.

It is impossible to ascertain the number of slaves imported into America. The estimates vary from 4,000,000 to 5,000,000. The larger number is probably an underestimate; but these figures do not represent the number shipped from Africa, for $12\frac{1}{2}$ per cent. were lost on the passage, one-third more in the "process of seasoning;" so that, out of 100 shipped from Africa, not more than 50 lived to be effective laborers.

Livingstone, who studied the question of slavery most carefully, estimated, that, for every slave exported, not less than five were slain or perished, and that in some cases only one in ten lived to reach America. If the lowest estimate is taken, then not less than 20,000,000 Negroes were taken prisoners or slain to furnish slaves to America. No wonder that many parts of Africa were depopulated.

Though the slave-trade with America has been suppressed, thousands are annually stolen and sold as slaves in Persia, Arabia, Turkey, and central and northern Africa. Wherever Mohammedanism is the religion, there slavery exists; and to supply the demand the slave-trade is carried on more extensively and more cruelly to-day than at any previous time. The great harvest-field for slaves is in Central Africa, between 10° south and 10° north latitude. From this region caravans of slaves are sent to ports on the Indian Ocean and the Red Sea, and thence shipped to Indo-China, the Persian Gulf, Arabia, Turkey in Asia, and even to Mesopotamia, wherever Mussulmans are found. The English at Suakin are a constant hindrance to this traffic; and therefore Osman Digna has so often within the past five years attacked Suakin, desiring to hold it as a port from which to ship slaves to Arabia. Other caravans are driven across the desert to Egypt, Morocco, and the Barbary States. Portuguese slave-traders are found in Central Africa, and, though contrary to law, deal in slaves, and own and work them in large numbers. Cameron says that Alrez, a Portuguese trader, owned 500 slaves, and that to obtain them, ten villages, having each from 100 to 200 souls, were destroyed; and of those not taken, some perished in the flames, others of want, or were killed by wild beasts. Cameron says, "I do not hesitate to affirm that the worst Arabs are angels of mercy in comparison to the Portuguese and their agents. If I had not seen it, I could not believe that there could exist men so brutal and cruel, and with such gayety of heart." Livingstone says, "I can consign most disagreeable recollections to oblivion, but the slavery scenes come back unbidden, and make me start up at night horrified by their vividness."

If the chief or pacha of a tribe is called upon for tribute by his superior, if he wishes to build a new palace, to furnish his harem, or fill an empty treasury, he sends his soldiers, armed with guns and ammunition, against a Negro tribe armed with bows and spears, and captures slaves enough to supply his wants.

The territory from which slaves are captured is continually extending; for, as soon as the European traveler has opened a new route into the interior, he is followed by the Arab trader, who settles down, cultivates the ground, buys ivory (each pair of tusks worth about $500 at Zanzibar or Cairo); invites others to come, and when they have become acquainted with the country, and gathered large quantities of ivory, and porters are wanted to carry the tusks to the coast, a quarrel is instigated with the Negroes, war declared, captives taken,—men for porters, women for the harem,—the villages are burned, and the caravan of slaves and ivory takes its route to the coast, where all are sold. We are told on good authority that during the past twenty years more slaves have been sent out than formerly were exported in a century. Wissmann tells us what he has seen:—

"In January, 1882, we started from our camp,—200 souls in all,—following the road, sixty feet wide, to a region inhabited by the Basonge, on the Sankuru and Lomami Rivers. The huts were about twenty feet square, divided into two compartments, the furniture consisting of cane and wooden stools; floor, ceiling, and walls covered with grass mats. Between the huts were gardens, where tobacco, tomatoes, pine-apples, and bananas were grown. The fields in the rear down to the river were cultivated with sweet-potatoes, ground-nuts, sugar-cane, manioc, and millet. Goats and sheep and fowls in abundance, homestead follows homestead in never-ending succession. From half-past six in the morning, we passed without a break through the street of the town until eleven. When we left it, it then still extended far away to the south-east. The finest specimens in my collection, such as open-work battle-axes inlaid with copper, spears, and neat utensils, I found in this village.

"Four years had gone by, when I once more found myself near this same village. With joy we beheld the broad savannas, where we expected to recruit our strength and provisions. We encamped near the town, and in the morning approached its palm-groves. The paths were no longer clean, no laughter was heard, no sign of welcome greeted us. The silence of death breathes from the palm-trees, tall grass covers every thing, and a few charred poles are the only evidence that man once dwelt there. Bleached skulls by the roadside, and the skeletons of human hands attached to the poles, tell the story. Many women had been carried off. All who resisted were killed. The whole tribe had ceased to exist. The slave-dealer was Sayol, lieutenant of Tippo-Tip."

Sir Samuel Baker was largely instrumental in the suppression of the slave-trade, and, while the rule of the English and French in Egypt was maintained, slavery was greatly diminished; but, since the defeat and death of Gen. Gordon, the slave-trade has rapidly increased, and is now carried on more actively than at any other time. The only obstacles to this traffic are the presence of Emin Pacha at Wadelai, the English and American missionaries, and English trading-stations on Lakes Victoria Nyanza and Tanganyika.

The slave-traders unite in efforts to destroy Emin Pacha, and to expel the missionaries and all European travelers and traders, except the Portuguese, and for this purpose excite the hostility of the Negro against the foreigner. In this they are aided by the Mahdi. The work of the Mahdi is largely a missionary enterprise. The dervishes who accompany his army are religious fanatics, and desire the overthrow of the Christians and Emin Pacha as earnestly as the slave-trader. Religious fanaticism is therefore united with the greed of the slave-trader to drive out the Christians from the lake region.

Aroused by these reports, and influenced by these views, Cardinal Lavigerie, for twenty years Bishop of Algiers and now Primate of Africa, last summer started a new crusade in Belgium and Germany against slavery and the slave-trade. The cardinal has organized societies, and is raising a large fund to equip two armed steamships for Lake Tanganyika and Lake Nyassa, the headquarters of the slave-trade, and offers, if necessary, to head the band himself. The Pope has engaged in the work, has contributed liberally to this fund, and sent three hundred Catholic missionaries to Central Africa. The slave-trade is carried on with arms and ammunition furnished by European traders. Without these arms, the slave-trade could not be successfully carried on, for the Negroes could defend themselves against slave-traders armed like themselves. While the demand for slaves continues, the slave-trade will exist, and will not cease until the factories of European nations are planted in the interior of Africa.

Mineral Wealth of Africa.

We are told in Phillips's "Ore Deposits" that the precious metals do not appear to be very generally distributed in Africa. More thorough research may show that this view is incorrect, and that there are large deposits of iron, copper, gold, and other metals in many parts of the continent. Gold is found on the Gold Coast, in the Transvaal, in the Sudan, and in Central Africa, but is only worked in surface diggings, excepting in the Transvaal; but near all these washings, gold nuggets of large size, and the quartz rock, have been discovered. In Transvaal the mines were worked a long time ago, probably by the Portuguese, then abandoned and forgotten. Recently they have been rediscovered, and worked by the English. In the Kaap goldfield in the Transvaal, three years ago, the lion and zebra, elephant and tiger, roamed undisturbed in the mountain solitudes, where there is now a population of 8,000, with 80 gold-mining companies, having a capital of $18,500,000, one-third of which is paid up. Barberstown, the chief mining-town, has two exchanges, a theatre, two music-halls, canteens innumerable, several churches and hotels, four banks, and a hospital. A railroad was opened in December, 1887, from the Indian Ocean towards these mines, 52 miles, and is being rapidly constructed 100 miles farther to Barberstown.

There is reason to believe that gold deposits equal to those of Mexico or California will yet be found in several parts of Africa. Copper is known to exist in the Orange Free State, in parts of Central and South Africa, and in the district of Katongo, south-west of Lake Tanganyika, which Dr. Livingstone was about to explore in his last journey. Rich copper ores are also found in the Cape of Good Hope, Abyssinia, and equatorial Africa. Large and excellent deposits of iron ore have been found in the Transvaal and in Algiers, and a railroad 20 miles long has been built to carry it from the Algerian mines to the sea. Very many tribes in equatorial and Central Africa work both iron and copper ores into different shapes and uses, showing that the ore-beds must be widely distributed.

One of the few large diamond-fields of the world is found in Griqua and Cape Colony, at the plateau of Kimberly, 3,000 feet above the sea. The dry diggings have been very productive; this tract, when first discovered, being almost literally sown with diamonds.

Coal has been found in Zulu-Land, on Lake Nyassa, and in Abyssinia. The latter coal-field is believed to be secondary. Iron, lead, zinc, and other minerals, have been found in the Orange Free State. Salt-beds, salt-fields, salt-lakes, and salt-mines are found in different parts of Africa.

RAILROADS.

The peculiar formation of Africa, its long inland navigation, interrupted by the falls near the mouths of its large rivers, from connection with the ocean, render it necessary to connect the ocean with the navigable parts of the rivers by railroads.

The Belgians will soon construct a railroad on the southerly side of the Kongo, to the inland navigable waters of the Kongo at Leopoldville, following the preliminary surveys lately completed; the French may also construct a road from the coast to

Stanley Pool; and by one or the other of these routes the interior of Africa will be opened.

South of the Kongo, the Portuguese are constructing a railroad from Benguela into the interior. In Cape Colony railroads connect the greater part of the British possessions with the Cape of Good Hope. A railroad is also being constructed from Delagoa Bay to the mines in Transvaal.

Sudan and the upper waters of the Nile can only be opened to a large commerce by a railroad from Suakin to Berber, about 280 miles. Surveys were made for this road, and some work was done upon it, just before Gen. Gordon's death. The navigation of the Nile above Berber is uninterrupted for many hundred miles. Below Berber the falls interrupt the navigation. The route from Gondokoro down the Nile is by boat to Berber, camel to Assuan, boat to Siut, and railroad to Cairo and Alexandria, making a route so circuitous that it prevents the opening of the Sudan to any extensive commerce.

In Algiers there are 1,200 miles of railroad, and more are being constructed. The French are constructing a railroad from the upper part of the Senegal River to the head waters of the Niger. The English have organized a company to construct a road from the Gold Coast to the mines in the interior.

It will thus be seen that the railroad has already opened a way into Africa that is sure to be carried on more extensively.

Stanley Expedition.

There are two methods of exploring Africa. One is where an individual, like a Livingstone, or a Schweinfurth, or a Dr. Junker, departs on his journey alone. He joins some tribe as far in the interior, on the line of exploration, as possible; lives with the tribe, adopting its habits and manner of life, learning its language, making whatever explorations he can; and, when the region occupied by such tribe has been fully explored, leaves it for the next farther on. This plan requires time and never-failing patience; but in this way large portions of Africa have been explored. The other way, adopted by Cameron, Stanley, Wissmann, and the Portuguese explorers, has been to collect a party of natives, and at their head march across the continent.

"An immense outfit is required to penetrate this shopless land, and the traveler can only make up his caravan from the bazaar at Zanzibar. The ivory and slave-traders have made caravanning a profession, and every thing the explorer wants is to be found in these bazaars, from a tin of sardines to a repeating-rifle. Here these black villains the porters—the necessity and despair of travelers, the scum of slave-gangs, and the fugitives from justice from every tribe—congregate for hire. And if there is any thing in which African travelers are for once agreed, it is, that for laziness, ugliness, stupidity, and wickedness, these men are not to be matched on any continent in the world." Upon such men as these Stanley was obliged to depend.

Though traveling in this way is more rapid than the other, it is very expensive, and has many difficulties not encountered by the solitary traveler. The explorer always goes on foot, following as far as possible the beaten paths. A late traveler says: "The roads over which the land-trade of equatorial Africa now passes from the coast to the interior are mere footpaths, never over a foot in breadth, beaten as hard as adamant, and rutted beneath the level of the forest-bed by centuries of native traffic. As a rule, these foot-paths are marvellously direct. Like the roads of the old Roman, they move straight on through every thing,—ridge and mountain and valley,—never shying at obstacles, nor anywhere turning aside to breathe. No country in the world is better supplied with paths. Every village is connected with some other village, every tribe with the next tribe, and it is possible for a traveler to cross Africa without being once out of a beaten track."

But if the tribes using these roads are destroyed, the roads are discontinued, and soon become obstructed by the rapid growth of the underbrush; or, if the route lies through unknown regions outside the great caravan-tracks, the paths are very different from those described by Mr. Drummond, for the way often lies through swamps and morass, or thick woods, or over high mountain-passes, or is lost in a wilderness of waters.

The great difficulty in these expeditions is to obtain food. As supplies cannot be carried, they must be procured from the natives. Very few tribes can furnish food for a force of six hundred men (the number with Stanley); and when they have the food, they demand exorbitant prices. Often the natives not only refuse food to the famished travelers, but oppose them with such arms as they have; and then it is necessary, in self-defence, to fire upon them.

The greatest difficulty the explorer meets comes either directly or indirectly from the opposition of the slave-trader. Formerly the slave-trader was not found in equatorial Africa; but, since the explorer has opened the way, the slave-trader has penetrated far into the interior, and is throwing obstacles in the way of the entry of Europeans into Africa. When it was decided that Stanley should relieve Emin Pacha, he was left to choose his route. He met Schweinfurth, Junker, and other African travelers, in Cairo. They advised him to go by his former route directly from Zanzibar to the Victoria Nyanza. The dangers and difficulties of this route, and the warlike character of the natives, he well knew. The route by the Kongo to Wadelai had never been traveled, and he thought the difficulties could not be greater than by the old route; and, beside, he proceeded much farther into the interior by steamer on the Kongo, which left a much shorter distance through the wilderness than by the Zanzibar route. On arriving at Zanzibar, he made an arrangement with Tippo-Tip, the great Arab trader and slave-dealer, for a large number of porters. They sailed from Zanzibar to the Kongo, where Stanley arrived in February, 1887. He then sailed up the Kongo, and arrived in June at the junction of the Aruvimi with the Kongo, a short distance below Stanley Falls. Stanley believed that the Aruvimi and the Welle were the same stream, and that by following up this river he would be on the direct route to Wadelai. Subsequent investigations have shown that he was mistaken. About the 1st of July he left the Kongo, expecting to reach Emin Pacha in October, 1887. No definite information has been received from him from that time to the present. He left Tippo-Tip in command at Stanley Falls, and expected that a relief expedition would follow. There were great delays in organizing this expedition, from the difficulty of obtaining men, and it was thought that Tippo-Tip was unfaithful. The men were finally procured, and the expedition left Aruvimi in June, 1888, under command of Major Barttelot. A day or two after they started, Major Barttelot was murdered by one of his private servants. The expedition returned to the Kongo, and was re-organized under Lieut. Jamieson. He was taken ill, and died just as he was ready to start, and no one has been found to take his place; and that relief expedition was abandoned. Reports say that Stanley found the route more difficult than he anticipated; heavy rainfall, rivers, swamps, and marshes obstructed the way; that the season was sickly, and a large part of his followers died long before he could have reached Emin Pacha.

The reports of his capture, and of his safe return to the Aruvimi River, are known to all. These may or may not be true. Although we have not heard from Stanley for a year and a half, yet it by no means follows that he is dead; for Livingstone, Stanley, and other explorers have been lost for a longer time, and have afterward found their way back to the coast. No man has greater knowledge of the country through which his route lay, or of the character of the natives, or the best manner of dealing with them. Emin Pacha was encamped quietly for nearly two years at Wadelai; and Stanley, in like manner, may have been compelled to remain at some inland point and raise his own provisions.

The Future of Africa.

It is impossible to prophesy the future of any country, much less that of Africa, where the physical features have left so marked an impression upon its inhabitants, and where the animal life is so different from that of the other continents. It is rather by differentiating Africa from other countries that we obtain any data from which to form an opinion of its future.

Africa, as we have seen, is surrounded by a fringe of European settlements. What effect will these settlements have upon Africa? Will the European population penetrate the interior, and colonize Africa? Will it subjugate or expel the Africans, or will they fade away like the Indians of our country? If colonization by Europeans fail, will the African remain the sole inhabitant of the country as barbarian or civilized?

Egypt is now controlled by the English, but its climate is too unhealthy, and its surrounding too unfavorable, for Englishmen; and we may safely assume that their occupation will be temporary, or, if permanent, not as colonists. They will remain, as in India, foreigners and rulers, until the subjugated people rise in their power and expel them, and return to their old life. The English rule, though possibly beneficial to Egypt, is hated by the natives, who demand Egypt for the Egyptians.

Leaving Egypt, we pass an uninhabitable coast, until we come to the French colonies of Algiers. It is nearly sixty years since the French took possession of Algiers. There has been a large emigration from France; but the climate, while excellent as a winter climate for invalids and others, is unfavorable for a permanent habitation, especially for infants. The births in one year have never equalled the deaths. When Algeria was first conquered by the French, it was a wilderness, but is now a garden. The cultivation of the grape has been most successful, and extensive iron-mines have been opened. The French are gradually pushing their way from Algiers across the desert to Timbuctu, and also from Senegambia to Timbuctu. The expense of maintaining Algeria has greatly exceeded any revenue derived from it. Though many doubt the political wisdom of retaining it, yet the French have too much pride to acknowledge that the enterprise has been in any way a failure; and they will undoubtedly hold it, and perhaps found an empire. Senegambia and the coast of Guinea, claimed by the French and English, are low and moist, filled with swamps and lagoons, which will prevent any European colonization.

South of the Kongo, the Portuguese claim a wide section of country running across Africa. They have occupied this country over two hundred years. They have done little towards colonizing, and only hold a few trading-posts on the coast and in the interior, dealing principally in slaves, ivory, and gold; and it may well be doubted whether they have the stamina or ability to colonize this country, or to produce any permanent impression upon it.

The south portion of Africa, from the 18th parallel on the Atlantic to the 26th parallel on the Indian Ocean, is generally fertile; and the climate is favorable to Europeans, and is capable of sustaining a large population. The growth of Cape Colony has been very slow, but a more rapid growth is anticipated. We believe it will be permanently occupied by the English, who will disposses the aborigines, and form a great and permanent English State. The coast of Zanzibar, occupied by the Germans and English, is rich and fertile, the climate unhealthy; but when the mountain-ranges are crossed, and the elevated plateaus and lake regions are reached, the interior resembles the Kongo region. Massaua and Suakin, on the Red Sea, are unhealthy and worthless, unless connected by railroad with the upper Nile.

There remains equatorial Africa, including the French settlements on the Ogowe, the region about Lake Chad, the Kongo and its tributaries, and the lake region. The more we learn of equatorial Africa, the greater its natural advantages appear to be. The rivers open up the country in a favorable manner for trade and settlement. Its elevation from 2,000 to 3,000 feet will render it healthy, though this elevation is only equal to from ten degrees to fourteen degrees of north latitude. Here all the fruits of the torrid zone, the fruits and most of the grains of the temperate zone, cotton, India-rubber, and sugar-cane, are found.

The country has been unhealthly, a great many Europeans have died, and few have been able to remain more than two or three years without returning to Europe to recuperate. These facts seem to show that the climate is not healthy for Europeans. But the mortality has been much greater than it will be when the country is settled and the unhealthy stations have been exchanged for healthier localities. Every new country has its peculiar dangers, which must be discovered. When these obstacles are understood and overcome, Europeans will probably occupy all this region, and it will become a European colony.

If European colonization is successful, European civilization will come into contact with African barbarism. Where such a contest is carried on in a country where the climate is equally favorable to the two races, it can only result in the subjugation or destruction of the inferior race. If the climate is unfavorable to the white population, then, unless the inferior is subjected to the superior, the white population will fail in colonizing the country, and the Negro will either slowly emerge from barbarism, or return to his original condition.

The Negro has never developed any high degree of civilization; and even if, when brought into contact with civilization, he has made considerable progress, when that contact ceased he has deteriorated into barbarism. But, on the other hand, he has never faded away and disappeared, like the Indian of America and the natives of the Southern Archipelago.

Nature has spread a bountiful and never-ending harvest before the Negro, and given to him a climate where neither labor of body or mind, neither clothing nor a house, is essential to his comfort. All nature invites to an idle life; and it is only through compulsion, and contact with a life from without, that his condition can be improved.

In Africa a contest is going on between civilization and barbarism, Christianity and Mohammedanism, freedom and slavery, such as the world has never seen. Who can fail to be interested in the results of this conflict? We know that Africa is capable of the very highest civilization, for it was the birthplace of all civilization. To it we are indebted for the origin of all our arts and sciences, and it possesses to-day the most wonderful works of man. Let us hope that Africa, whose morning was so bright, and whose night has been so dark, will yet live to see the light of another and higher civilization.

APPROPRIATION OF AFRICA BY EUROPEANS.

REPORT—GEOGRAPHY OF THE LAND.

By Herbert G. Ogden.

In preparing this first report as one of the vice-presidents of the Society, I have been obliged to interpret the intent of our by-laws in the requirement that the vice-presidents shall present at the end of the year summaries of the work done throughout the world in their several departments. The amount of information that can be accumulated during twelve months, if referred to in detail, is simply appalling; to compile it for the Society would be a great labor, and when completed it would be largely the duplication of the work of others, already accessible in the journals of other societies, and in special publications devoted to this and kindred subjects. That such a detailed historical journal should be maintained by the Society hardly admits of a question. I had hoped to see one inaugurated during the first year of our work that would have embraced all the departments of the Society: but must confess with some disappointment, to having been too sanguine and to have over-estimated the interest that might be excited in the members of a new organization. We need a journal of the kind for reference; for our associates, ourselves, and our many friends we hope to attract by the information we may supply them. But it cannot well be compiled by one man engaged upon the every-day affairs of life, and I have not made any attempt in that direction, even in those matters circumscribed by the section of the Society under my charge.

I have found little in the affairs of Europe that it seems necessary to bring to your attention; indeed, the past twelve months seem quite barren of any great events in the progress of Geographic knowledge. This, perhaps, is to be expected at intervals of longer or shorter periods, as it is governed by peoples of the most advanced civilization, who have availed themselves of all the progress of science to explore and develop the land on which they live, until there is little left of nature to be learned, unless science shall determine new truths to bind by stronger links the truths already found. We may look for the greatest changes here, both now and in the future, in the work of man pressing on in the eager strife to improve his condition above others less fortunately situated; seeking advantage in the peculiarities of his environment to open new channels of trade that will divert the profits from the older routes.

Of many schemes suggested in furtherance of such ends, there are few that develop into realities within a generation. Nature may be against them when the facts are fully learned, the profit may not warrant the outlay, and political considerations may keep in abeyance that which otherwise may be admitted to be good. Thus the grand scheme to make an inland sea of the Desert of Sahara is impossible of execution from the fact that the desert is many hundreds of feet higher than the ocean. The long talked of project to cut the Isthmus of Corinth, now accomplished, was a theme of discussion for twenty centuries or more. And the later project to tunnel the English Channel we have seen defeated through the fears of a few timid men. Perchance the grander one, now introduced with some seriousness, to bridge the channel, may meet with a better fate.

The route for the ship canal to connect the Baltic and the North Seas, is reported to have been determined upon and the preliminary work of construction to have been commenced. And we learn that a proposition is being discussed to connect the Danube with the Baltic Sea by way of the Vistula. However chimerical such a project may seem to us, we cannot at this time discredit those who believe in it. It shows that restless spirit that predominates the age, striving for the mastery of the commercial world. Politically, Europe has seen no geographical change, but those conversant with affairs apprehend a military catastrophe at no distant date, that will probably embroil the stronger nations and endanger the existence of the weaker ones.

Having practically acquired a knowledge of their territories, the people of these nations are diligently seeking to develop greater things in the study of all the earth, and we have thus seen formed as a means to this end, what is now known as the International Geodetic Association. The primary object of this Association is to determine the form of the earth. It is an inquiry of absorbing interest, and the geodetic work in America must eventually contribute an important factor in its solution. We may therefore hope that the bill now before the Congress authorizing the United States to have representation in the Association, will become a law. The free interchange between the continents that would thus be established, would be of incalculable benefit to both in the prosecution of this important scientific labor.

If we turn to the adjoining continent of Asia, there is still open a large field for Geographic research. Peopled as it has been, largely by semi-civilized races for many centuries, we might have expected that the book of nature that might be opened would long since have been spread before us ; but the exclusiveness of this semi-civilization has been a stumbling-block, until it may be said that the wise men of her nations have lived only that the masses should not learn. Of the Political Geography of this great region we have a fair conception, and of the Physical conditions it may be said we know them generally. Enlightened men have been hammering at the borders with the powerful support of progressive nations, and a few have even passed the confines of exclusiveness and brought back to us marvellous tales of ancient grandeur. Men have sought disguise that they might tread on the forbidden ground, and many have lost their lives in efforts to gain the secrets that have been so persistently guarded. But the march of civilization is not to be thwarted by the semi-barbarous ; they may yet impede it, as they have in the past, but it can be only for a time ; the impulse is sure to come, when the thirst for knowledge and power by the antagonistic races will sweep all barriers before it, however strong. The contemplated railway across the continent to Vladivostock may be the culminating step in overcoming these refractory peoples and opening their territories to the march of progress. We have seen on our own continent the potent influence of these iron ways, and it is not too much to believe that even in the strange surroundings of the Orient they will exercise a power against which exclusiveness and superstition will be forced to give way.

In Africa we find still different conditions. A great continent believed to contain immense resources, but peopled with dark-hued native races, barbarous in their tendencies, and frequently deficient in intellect, and yet withal showing at times a savage grandeur that excites the admiration of the man, while it attracts the interest of the student. We may recall Carthage and Alexandria, and all the wonders of ancient Egypt that live to the confusion of our own day, while those who patterned them have been lost beyond the bounds of even the most ancient history : and look with trembling awe upon the degradation that has followed, the boundless dissipation of the learning of ages, until we are left only such remnants that our most cultivated imaginations can scarce build a superstructure worthy to raise upon the ruins.

But a new era is opening, the intelligence of later years is spreading over these once fruitful fields, and slowly but surely modern ideas are advancing into the midst of the unknown chaos, and in time will restore the great advantages that have lapsed in the ignorance of ages. The nations of Europe vie with one another to extend their possessions, and in the mad race for precedence are reclaiming even the waste places as footholds by which they hope to reach the power and wealth they see may be developed in the future. Explorers have brought back wondrous tales that have excited the cupidity of those who profit in the barter of nature's products, until vast schemes have been projected to seize the wealth believed to be within easy grasp.

Daring spirits discover new countries, and through the reports of the marvels they have seen, inspire their more cautious countrymen to venture into unknown fields in the hope of gain. The discontented, too, seek isolation and fancied independence in new regions, and thus is formed the nucleus that parent countries seize upon, encourage, and develop into colonies, that in time may revolutionize a continent, and seek a place among the nations of the world. This sequence of events has been gradually progressing in Africa, and has been greatly accelerated by the discoveries of recent years. A large section of the interior has now been opened to trade and colonization in the formation of the "Congo free State." It marks an era in the development of the continent that promises to be fruitful of rapid advance. The Geographic journals have contained many pages of notes during the year, showing the activity of explorers in supplying the Geographical details of the more accessible regions. But there is an area nearly half as large as that of the United States through which the explorer has not yet penetrated ; a field of great interest to Geographers, but they may have years yet to wait, before they may read the story.

In the East Indies and among the islands of the Pacific there is still work for the Geographer of the most interesting character, and, indeed, for the explorer too. Those who depend upon charts of the great ocean realize too frequently the imperfect determination of the positions of many of these isolated landmarks, and the dangers surrounding them. This is more properly work for governments than for individuals, and we may hope the day is not far distant when American officers may again roam the seas in Geographic research, and bring fresh laurels to crown the enterprise of our people.

The great American continent, the New World as it is called, presents an example of progress of which history affords us none similar—a marked instance of the power of intelligent perseverance to conquer in new fields and bring under man's dominion for his use and welfare even some of the elements themselves. The last century has shown a branch of one of the old parent stocks, divorced from many of their traditions and left to themselves, imbued with a spirit of progress that has advanced with such giant strides, that in a generation we have seen more strange things than had come upon the world before in centuries. At the birth of our nation the now populous district on the Ohio and the Great Lakes was the "far west," roamed over by native tribes. The great northwest of to-day was marked upon the maps as "unexplored," and the confines of the continent on the Pacific were known more on the faith of good reports than the knowledge of observation ; while that vast territory west of the Mississippi was not known at all, or only through the legends transmitted from the "Fathers" who had partly occupied it in following their holy calling. And yet within half a century explorers have traversed nearly every square mile, science has discovered in it treasures of knowledge that have taught the world : and instead of a vast region of wandering tribes, we find a civilization, energetic, progressive, and still pressing on to reclaim even that which has been considered waste. Indeed, so rapidly have the choice areas been occupied, that it may be but a few years when none will be left, and the question of over-population may press upon us as to-day it presses upon older nations. While this state of affairs may not excite present alarm, it is a matter of congratulation that the Congress at its last session provided the initial step for an exhaustive examination of the great arid region, to determine what portion of it may be reclaimed by irrigation.

And in Alaska the desirability of a better knowledge of our possessions has been emphasized by the fear of international complications on the boundary, which has resulted in a small appropriation by the Congress for surveys, with a view to obtaining a better knowledge of the country, whereby a more reasonable delimitation of the boundary can be made.

It is gratifying to note that the Bureaus of the Government service devoted to the practical development of the economic resources of our great territory, have been conducted during the year with the energy that has marked their progress heretofore. But it is yet too early to place a value upon the special results of the year's work, and I will leave their consideration, therefore, to my successor.

I look upon the publications of the Topographical Surveys of the States of New Jersey and Massachusetts as the most noteworthy Geographic productions in this country of recent years. Massachusetts has been the first State to avail herself of the full facilities offered by the General Government in preparing maps of their territories on working scales, although New Jersey was earlier in the field and obtained all the assistance that could be rendered by the laws in force at the time. The expense of the Survey in Massachusetts has been borne about equally between the State and United States, exclusive of the trigonometrical work; and the total cost to the State being so light, we may hope eventually to see similar, or even more detailed work, undertaken by all the States of the Union. The atlas sheets thus far produced are most pleasing specimens of the cartographer's art, each feature or class of detail having been given a weight that permits easy reading without producing undue prominence in any. In the atlas sheets of New Jersey, published by the State, the same admirable effects have been produced, but in a different style of treatment, the questions involved being more complicated through the introduction of greater detail. Massachusetts is also in the lead in prosecuting a precise determination of town boundaries by a systematic reference of all corner marks to the stations of the triangulation that now covers the State territory. The expense of this work is borne by the State, with the exception of a small amount in salaries to United States officers detailed to execute portions of the work under existing laws. The total cost will probably approximate the total cost of the Topographical Survey, but it is claimed that when completed the great advantages to be derived from it will result in large savings to the people of the State.

Our neighbors in the Dominion of Canada have been active of late years in developing their resources. The completion of the Canadian Pacific Railway has opened a large fertile territory for settlement, and the railway itself promises to become a route for international traffic in serious rivalry with the transcontinental roads in the United States. Projects have also been formed for a short rail connection to Hudson's Bay, with a view to shipments during the summer direct to Europe—but there seems to be reasonable question of the practicability of such a route. During the past two seasons Canada has also been engaged upon extensive explorations in the Northwest territory, along the boundary line of Alaska. The parties, I learn, are only just returning from their last summer's labors, and it will probably be some time in the winter before we can supplement the chapter of a year ago from this interesting region.

But little advance has been made during late years in solving the mysteries of the Arctic. In the past summer a party has crossed the southern part of Greenland, but advices have not yet come to hand that would indicate the value of the exploration. A second party was organized to follow the east coast of Greenland to the northward, that we may hear from at a later date, although reports already received, if true, would indicate the effort had been baffled by adverse weather. A few months ago an expedition was seriously contemplated by Europeans to the frozen seas of the Antarctic. As it was to have been backed by energetic business men it doubtless would have been amply fitted for its purpose, and we may, therefore, sincerely regret the rumor that the project has been postponed—if not abandoned.

In the Central American States a Congress has been assembled to consider the unification of the States under one general government—a union, the possibility of which has long been discussed, but from the jealousy of rival factions has heretofore seemed impossible of accomplishment; but there is some hope that the labors of the Congress now in session will prove more successful.

Our greatest Geographic interest in these States is centered in the projects for interoceanic canals. The scheme to cut the Isthmus of Panama, undertaken by the eminent French engineer, De Lesseps, has been beset with many difficulties, not the least of them arising from the improvident management of those having immediate charge of the works. It is impossible to foresee the eventual outcome of this great work, as all reports expressing decided views on the subject are suspected of a coloring from the personal opinions of the authors of them. The original plans have been modified to include locks for crossing "a summit level."

This is stated to be only a temporary expedient to secure the opening of the canal at an early date, and that eventually the work will be completed on the original plan of a "through cut." It seems evident from the latest reports that work will be continued as long as money is forthcoming to meet the expenses, and as the modified scheme to overcome the high land by locks instead of a through cut, greatly simplifies the engineering problems, there is a probability of the canal becoming an accomplished fact. A second route by way of the San Juan River and Lake Nicaragua, that has also been under discussion for many years, has recently been energetically advocated by American engineers, with the result of the actual location of a line and careful cross-sectioning during the past year. A company has been formed and obtained a charter from the State of Vermont, and as it is represented to be backed by abundant capital, we may, ere many years, have the gratification of seeing an interoceanic canal opened under American auspices.

Many speculations have been indulged in as to the probable effect of a canal through this Isthmus on the carrying trade of the world, the impetus it might give to the opening up of new commercial relations, and even the effect it may have in advancing our civilization to distant nations. Such speculations are hardly pertinent to this report, but we may well reflect upon the changes that have been wrought since the opening of the canal through the Isthmus of Suez, and conceive, if we can, the leveling up that may accrue to the political divisions of the western world from the same influences that will cut the channel through her Isthmus.

South America has been free from serious agitation until a recent date; although some of the States have not failed to show the usual internal dissensions in political affairs. Late advices intimate a possible difficulty between Venezuela and England relative to the control of a large territory embracing the mouth of the Orinoco River, which, should it result in the permanent occupation of the disputed territory by the European power, may wield a marked influence in the development of this section of the continent.

A project that has long been agitated, to construct a continental railway that would give direct rail communication with the northern continent, has recently been resumed, and we can but hope with an earnestness that will lead to its accomplishment.

Large areas of this interesting country have not yet been revealed to us, nor can we expect to acquire a full knowledge of its Geographic wonders until the means of internal communication have become more assured.

The recent inauguration of a Geographical Society in Peru is also an important step towards our acquirement of more detailed information, and doubtless will redound to the credit of its founders in the interest it will stimulate in kindred societies over the world.

Geology is a science so intimately connected with Geography that I should feel delinquent did I not include a reference to it in this report, however inadequate my remarks may be to do justice to the subject.

To Geographers the origin of the varied distribution of the land and water, the cause and growth of mountains, plains, oceans, lakes and rivers, the great changes that have taken place on the face of the earth in times past, is of absorbing interest, rivaled only by their desire for perfect knowledge of that which may be seen to-day. Had the prehistoric man been gifted with the intelligence of his descendants in the present epoch, he would have left for us a record that would have been valuable indeed and cleared our way of much that now is speculation, and but too often food for words. True it is, however, that if the mysteries of the past were revealed to us we should lose the pleasures their study affords and perhaps there would follow a degeneration of species through the loss of stimulus they now provide. How long ago man lived and might have made a record is still a disputed question, but one that involves too, the record of the earth herself. The association of human remains in the Glacial drift brings that epoch in the earth's history nearer to us by several hundred thousand years, and instead of speculating upon it as having occurred nearly a million years ago, geologists must consider whether it was not probably coincident with the most recent eccentricity of the earth which astronomers teach us happened about ten or fifteen thousand years ago. Geology must also fit her facts to mathematical science if we give credence to latest computations. A mathematician has now advanced the theory that at the average depth of about five miles below the surface there is a belt of "no strain," the result of opposing forces above and below it, a belt that from the nature of the case is impenetrable, through which, what is above cannot pass to what is below, and what is below cannot pass to what is above, a condition that would confine the origin of all seismical and volcanic disturbances and their consequent Geographical changes, to a mere shell of the crust.* The result of the computation is certainly interesting and we may hope will not be lost sight of in future discussions, however it may share in gaining support or opposition. It is based upon an assumption of the temperature when the earth began to cool, to assume a lower temperature draws the belt nearer to the surface and a higher temperature is believed to be inconsistent with our knowledge of what heat may effect. This belt is stated to be gradually sinking, however, and the computation, therefore, involves a term representing time, and I venture to suggest as estimates of Geologic time are generally indefinite and seem to be inexhaustible, an abundance can probably be supplied to sink the belt deep enough for all theoretical purposes.

More interesting to Geographers are the conceptions of ancient forms suggested by the views recently advanced by Prof. Shaler in a late number of Science (June 15, 1888), on "The Crenitic Hypothesis and Mountain Building." To let the imagination have full play, we may conceive that where we now have extensive mountain ranges, there were formerly great plains of sedimentation, and where we see the process of sedimentation active to-day there may be great mountains in the future. And also in his inquiry into the "Origin of the divisions between the layers of stratified rocks" (Proced. Boston Soc. Nat. Hist., vol. xxiii), we may be carried away with the immensity of the changes suggested. The recurring destruction of submarine life to contribute in the building of the rocks of the Continents : the apparently endless cycles of emergence of the land and subsidence of the waters, to leave the Geographical conditions we see to-day, furnish additional evidence of the wonders of the past and force upon us anew the realization of how little in the great evolution is the epoch in which we live.

American Geologists have advanced the knowledge of the world; only recently the American methods of Glacial study have enabled Salisbury to interpret the terminal moraines of Northern Germany (Am. Jour. Science, May, 1888), and that the Science is active among our countrymen is evidenced by the formation of a Geological Society and the establishment of a magazine de-

* In the American Geologist for February, 1888, Prof. Reade protests against the construction of the theory of a "belt or level of no strain" placing the foci of earthquakes and other disturbances in the strata above the belt.

voted exclusively to its interests. America, too, contributed largely to the Geologic Congress recently held in London, and it is pleasing to note that the next session of the Congress is promised for Philadelphia.

At the suggestion of one of our associates I call the attention of the students of the science, and indeed all interested in it, and also of Geographers, to a recent publication entitled, "The Building of the British Isles," by Jukes-Browne (Scribner & Welford, N. Y.). It has been characterized as the best treatise on the evolution of the land areas which has yet appeared ; from the Geologist point of view it is the book of the year. Another associate recommends to most attentive consideration the recent articles on "Three formations of the Middle Atlantic slope," by W J McGee (Am. Journal Science, Feb.–June, 1888), as one of the most original essays of recent years.

It also gives me great pleasure to bring to your attention an article on the "Physical Geography of New England," by Wm. M. Davis, in a book on the "Butterflies of New England," by S. H. Scudder. It is hardly necessary to recommend this publication to your perusal, as I doubt not being from the pens of our Associates, it will excite a lively interest in those devoted to these sciences.

In conclusion permit me to refer briefly to the "National Geographic Magazine," published by the Society, the first number of which has recently been placed before you. It is the desire of the Committee having charge of this publication to make it a journal of influence and usefulness. There is abundant material in the Society to furnish the substance, if those who have it at command will make legitimate use of their opportunities. It would be unfortunate if the text should be confined to the papers presented to the Society. It was not the intention of the Board of Managers that such should be the case, when the publication was determined upon. On the contrary, it was the expectation that there would be original communications from many sources: essays, reviews and notes on the various subjects of the five Departments in which the Society is organized, not necessarily from the members, but also from their friends interested in these divisions of the general subject. While this expectation has been realized in a measure, there is room for improvement and it is hoped the future will show an increasing interest and more generous contributions.

December, 1888.

REPORT—GEOGRAPHY OF THE SEA.

By George L. Dyer.

In presenting to the National Geographic Society this first annual summary of work accomplished in the domain of the Geography of the Sea, I find it impossible satisfactorily to limit the range of subjects that may be assigned to it. The great ocean is so large a factor in the operations of Nature, that the attempt to describe one of its features speedily involves the consideration of others lying more or less in that shadowy region which may be claimed with equal force by other sections of the Society. It is to be understood, therefore, that the following account merely touches upon several of the characteristics of the oceanic waters, and is not in any sense an attempt to treat them all.

This being the first report to the Society it has been thought advisable to give a brief outline of the progress made in our knowledge of the sea since 1749, when Ellis reported depths of 650 and 891 fathoms off the north-west coast of Africa. Even at that time an apparatus was employed to lift water from different depths in order to ascertain its temperature. It does not appear that this achievement gave impetus to further efforts in this direction, for, except some comparatively small depths and a few temperatures recorded by Cook and Forster in their voyage around the world in 1772–75, and in 1773 by Phipps in the Arctic, at the close of the last century there was but little known of the physical conditions of the sea.

At the beginning of the present century, however, more activity was shown by several governments, and expeditions sent out by France, England and Russia, in various directions, began to lay the foundation of the science of Oceanography.

Exploration of little known regions was the main purpose of most of these expeditions, but attention was paid also to the observation and investigation of oceanic conditions, so that accounts of soundings, temperatures of sea water at various depths, its salinity and specific gravity, the drift of currents, etc., form part of their records.

The first to give us a glimpse of the character of the bottom at great depths was Sir John Ross, the famous Arctic explorer.

While sounding in Ponds Inlet, Baffin Bay, in 1819, by means of an ingeniously constructed contrivance called a deep sea clam, he succeeded in detaching and bringing up portions of the bottom from depths as great as 1,000 fathoms. The fact that this mud contained living organisms was the first proof of life at depths where it was thought impossible for it to exist. The truth of this discovery, however, was not generally accepted, many eminent men of science on both sides of the Atlantic contending for and against it, and the question was not finally settled until long afterward, in 1860, when, by the raising of a broken telegraph cable in the Mediterranean, unimpeachable evidence of the existence of life at the greatest depths in that sea was obtained. The science, however, remained in its infancy until about 1850, when Maury originated his system of collecting observations from all parts of the globe, and by his indomitable energy aroused the interest of the whole civilized world in the investigation of the physical phenomena of the sea.

Through Maury's efforts the United States Government issued an invitation for a maritime conference, which was held in Brussels in 1853 and attended by representatives of the governments of Belgium, Denmark, France, Great Britain, Netherlands, Norway, Portugal, Russia, Sweden and the United States. The main object of the conference, to devise a uniform system of meteorological observations and records, was accomplished. According to the agreement, ships' logs were to have columns for recording observations of the following subjects : latitude, longitude, magnetic variation, direction and velocity of currents, direction and force of wind, serenity of the sky, fog, rain, snow and hail, state of the sea, specific gravity and temperature of the water at the surface and at different depths. It was also proposed that deep-sea soundings should be taken on all favorable occasions, and that all other phenomena, such as hurricanes, typhoons, tornadoes, waterspouts, whirlwinds, tide-rips, red fog, showers of dust, shooting stars, halos, rainbows, aurora borealis, meteors, etc., should be carefully described, and tidal observations made when practicable.

The practical results of this conference were great. The systematic and uniform collection of data by men of all nations is going on uninterruptedly to-day, and is furnishing the means for the solution of many of the problems relating to the Geography of the Sea.

An epoch in the progress of this science is marked by the appearance of Maury's Wind and Current Charts, his Physical Geography of the Sea, and his Sailing Directions, which contain the record of the first deep soundings taken by United States vessels; and to the United States, through Maury's efforts, belongs the honor of having inaugurated the first regular cruise for the purpose of sounding in great depths.

Under the instructions of Maury the U. S. brig Dolphin, commanded by Lieutenant Lee, and subsequently by Lieutenant Berryman, was detailed in 1851–3 to search for reported dangers in the Atlantic, and to sound regularly at intervals of 200 miles going and returning. The Dolphin was provided with Midshipman Brooke's sounding apparatus and with it succeeded in obtaining specimens of the bottom from depths of 2,000 fathoms. About the same period the U. S. ships Albany, Plymouth, Congress, John Adams, Susquehanna, St. Louis and Saranac also made soundings in various localities, and to the U. S. S. Portsmouth, in 1853, belongs the honor of having reported the first really deep-sea sounding obtained in the Pacific, 2,850 fathoms, in about 39° 40′ N., and 139° 26′ W.

The practicability of this work was thus fully demonstrated, and, although some of the earlier results, through defective appliances and lack of experience, were not entirely trustworthy, its character and success will always be a tribute to American enterprise and ingenuity.

With the advent of the submarine telegraph the investigation of the depth and configuration of the ocean bed became of vital importance, and the work of sounding for that purpose was taken up with activity; one of the first voyages in the interest of these projects was that of the U. S. S. Arctic, under the command of Lieut. O. H. Berryman, in 1856, between St. Johns, Newfoundland, and Valentia, Ireland.

The civil war naturally put a stop to these operations by United States ships. The U. S. schooner Fenimore Cooper was about the last engaged in this work, sounding in 1858–59 in the Pacific to 3,400 fathoms, and also reporting a sounding of 900 fathoms only $\frac{3}{4}$ of a mile west of Gaspar Rico Reef, in about 14°41′ N. and 168° 56′ E.

The work so well begun by the Americans was quickly taken up by other governments, and we find from that time to the present, the records of a large number of expeditions for diverse scientific observations in all parts of the world. Continued improvements in the appliances and instruments have made the results more precise than was possible in the earlier times, and, as the data accumulate, the bathymetric charts of the oceans are becoming more accurate. Not until this work is much further advanced, however, shall we be able to arrive at an estimate of the depths and weights of the oceans at all comparable to our knowledge of the heights and weights of the various great land masses above sea level.

Other important results of these expeditions have been the verification of many reported elevations of the ocean bed formerly considered doubtful, the discovery of new ones, and proof of the non-existence of others, which had been reported as dangers to navigation.

The Geography of the Sea reached a decidedly more advanced stage by the inception of several great scientific expeditions, of which that of the Lightning, in 1868, to the Hebrides and Faroe Islands, under the superintendence of Professors Carpenter and Wyville Thompson, was the forerunner. This was followed by the three years' cruise of the Challenger (Br.) in 1873–75, the Tuscarora (Am.) in 1874, and the Gazelle (Ger.) in 1875, by those despatched under the authority of the U. S. Coast Survey and of the U. S. Fish Commission, and others of lesser importance, sent out under the auspices of European governments, and by private individuals. All of these have contributed in an eminent degree to the progress of the science by giving us a better understanding of the physical and biological conditions of the sea at all depths. Special mention must be made of the splendid work that is being done continually by the expeditions sent out by the U. S. Fish Commission. This branch of the United States service, originally established for the investigation of the causes of the decrease in the supply of useful food fishes and of the various factors entering into that problem, in pursuance of these objects has been prosecuting a detailed inquiry, embracing deep-sea soundings and dredging, observation of temperatures at different depths, transparency, density and chemical composition of sea-water, investigation of surface and under currents, etc. ; in other words, making a complete exploration of the physical, natural and economic features of the sea, besides collecting a large number of specimens of natural history. The expeditions sent out by this Commission have brought to light from the deep beds of the ocean an extraordinary variety of animal life, previously unknown to science. Few vessels have furnished a greater number of deep-sea soundings than the F. C. S. Albatross. This steamer has explored fishing grounds on the east and west coasts of the continent; and since the beginning of last year has made a cruise from the North to the South Atlantic along the east coast of South America, through Magellan Strait, and northward along the west coast to Panama and the Galapagos Islands, and thence to San Francisco and Alaska; the scenes of her latest operations have been the plateau between the Alaskan coast and Unalaska and the banks off San Diego, California.

A large share in the progressive state of the science of the Geography of the Sea must also be credited to the systematic collection of marine observations by the Hydrographic Offices and other institutions all over the world. This forms the stock from which, as I have already indicated, must be drawn, through intelligent reduction and deduction, a better knowledge of the intricate laws governing the various phenomena of the sea and air.

Oceanic Circulation.

The existence of currents in certain localities was known at a very early date, and navigators in their voyages to the new world soon discovered the Gulf Stream and other currents of the Atlantic. The first current charts were published more than two hundred years ago. Theories were soon advanced to explain the causes, one group of scientific men attributing the origin of currents to differences of level produced by an unequal distribution of atmospheric pressure over the oceans, another set connecting the tidal phenomena with the cause of ocean currents, and still another finding in the rotation of the earth a sufficient reason for their existence. The polar origin of the cold deep water found in low latitudes has long been considered probable, and has given rise to a theory of a general oceanic circulation in a vertical and horizontal direction, produced by differences of temperature and density. Recent theoretical investigations, however, seem to indicate that these causes alone are incapable of producing currents, and, to-day, the theory that the winds are mainly responsible for all current movements very largely predominates. Benjamin Franklin was probably the first who recognized in the trade winds the cause of the westerly set in the tropics, and Rennel soon after made the division of drift and stream currents. The objections which have appeared against the wind theory have been met with the reply that the present state of oceanic movements is the result of the work done by the winds in countless thousands of years.

Current phenomena is briefly summarized as follows by one of the latest authorities on the subject :

1. The greater portion of the current movement of the ocean must be regarded as a drift, produced by the prevailing winds, whose mean direction and force are the measures for the mean set and velocity of the current.

2. Another group of currents, and in fact a fraction of all currents, consists of compensating or supply streams, created by the necessity of replacing the drifted water in the windward portion of the drift region.

3. A third group results from drifts deflected by the configuration of the coasts ; these which are denominated free currents, quickly pass into compensating streams.

4. The deflecting force of the rotation of the earth is considered as of subordinate importance, but may have some influence on currents that are wholly or in part compensating or free.

Late investigations of the Gulf Stream by the U. S. Coast Survey give interesting facts in regard to that notable current.

A satisfactory explanation of the cause of the stream has not yet been found, but many believe, with Franklin, that the powerful trade drift entering the Gulf of Mexico through the broad channel between Yucatan and Cuba presses the water as a strong current through Florida Strait, where the stream is turned to the northward along the coast. Since 1850 American naval officers have added greatly to our knowledge of the characteristics of this stream, particularly within the last decade, during which notable investigations have been carried on by Commanders Bartlett and Sigsbee and Lieut. Pillsbury, U. S. N., under the direction of the U. S. Coast Survey, and by Lieutenant Commander Tanner, U. S. N., in the Fish Commission steamer Albatross.

Of special importance are the valuable and interesting results in regard to tidal action in the stream obtained by Lieut. Pillsbury, U. S. N., in the Coast Survey steamer Blake, from observations begun by him in 1885 at the narrowest part of Florida Strait, between Fowey Rocks and Gun Cay (Bah.), and continued since between Rebecca Shoal and Cuba, and between Yucatan and Cape San Antonio (Cuba), and off Cape Hatteras.

During the past year Lieut. Pillsbury extended the field of operations to the passages between the islands encircling the Caribbean Sea, and in order to study the Atlantic flow outside the limits of the trade drift a station was to have been occupied about 700 miles to the north-east of Barbados; this, however, was unfortunately prevented by bad weather.

The deductions from the observations in Florida Strait showed very clearly a *daily* and a *monthly* variation in the velocity of the stream, the former having a range of $2\frac{1}{2}$ knots, and reaching a maximum on the average about $9^h\ 9^m$ before and $3^h\ 37^m$ after the moon's upper transit, and the monthly variation reaching its maximum about two days after the maximum declination of the moon. The variations in this section were found greater on the western than on the eastern side of the strait, and the axis of the stream, or position of strongest surface flow, was located by Lieutenant Pillsbury $11\frac{1}{2}$ miles east of Fowey Rocks, and, farther north, about 17 miles east of Jupiter Light. The average surface current at this section was $3\frac{3}{5}$ knots, the maximum $5\frac{1}{4}$ knots, and the minimum $1\frac{3}{4}$ knots per hour. The results also indicate that when the current is at its maximum the surface flow is faster than at any depth below it, but when at its minimum the velocity at a depth of 15 fathoms or even down to 65 fathoms is greater than at the surface, and that there is at times a current running south along the bottom in all parts of the stream except on the extreme eastern side.

The results of the investigations in 1887 and 1888 have not yet been published, but from information kindly furnished by the authorities of the Coast Survey, I am able to give a brief outline of the more prominent facts ascertained.

In the section between Rebecca Shoal and Cuba the daily variation in velocity was found as prominent as in Florida Strait, the mean time of eight maxima corresponding to $9^h\ 18^m$ before, and that of three maxima to $3^h\ 25^m$ after the moon's transit. The axis of the stream in this section was found near the center of the current prism, and the flow was easterly and inclined on either side toward the axis. The axis seemed to occupy a higher level than other parts of the stream, and this appears to be borne out by the fact that about half the number of the current bottles thrown out in Florida Strait on the west side of the axis were recovered along the east coast of Florida, while of those thrown out east of the axis not a single one was heard from. As a rule it was found that the stronger the current the more constant the direction and the deeper the stratum. Remarkable fluctuations in the flow near the axis were noted, the velocity increasing sometimes one knot in ten or fifteen minutes, and then as suddenly decreasing again. Lieutenant Pillsbury attributes this, however, to a serpentine movement of the maximum flow, which would sometimes strike the station occupied by the Blake. The edge of the stream was found at about 30 miles south of Rebecca Shoal light-house.

Between Yucatan and Cape San Antonio the stream was found flowing about north, and the line of maximum velocity corresponds on the average to 10^h before and to 2^h 20^m after the moon's transit. The excessive variations were like those in Florida Strait, on the west side of the stream, and the maximum velocity of $6\frac{1}{4}$ knots was found about 5 miles off the 100-fathom line of Yucatan Bank. The eastern edge of the stream lies about 20 miles west of Cape San Antonio, and between this edge and the island, eddy currents exist. At the time the easternmost station in this section was first occupied, the declination of the moon was low and the set of the surface current north-easterly. At a high south declination of the moon the surface current was found south-easterly in direction, and east or south-east below the surface. The normal flow below the surface was in each case from the Gulf into the Caribbean Sea, and this makes it probable that the station was situated inshore of the average limit of the stream. On Cape San Antonio Bank the currents are tidal, flood running northward and ebb southward. On the Yucatan Bank the currents were also tidal, but as the edge of the bank is approached the stronger flow of the Gulf Stream predominates. The monthly variation in velocity, which was found clearly defined at the first two sections occupied, appeared at this section to be obliterated by anomalies not existing at the former.

Off Cape Hatteras the Blake accomplished the remarkable feat of remaining at anchor in 1,852 fathoms, and this with a surface current of over 4 knots. Two stations were occupied, and similar variations in velocity were observed as at the other stations. The notable feature at this station was the discovery of tidal action beneath the Gulf Stream, the currents at 200 fathoms depth changing their direction very regularly, the average current flowing about S. S. E. ½ E. for 7 hours and N. N. W. ½ W. for a little over 5 hours.

The first section investigated in 1888 was in the equatorial drift between Tobago and Barbados, where seven stations were occupied. The axis of the stream was found west of the middle, or nearer the South American shore, and the average direction was towards the north. At none of the stations did the current set in the direction of the wind, although the trades were blowing at all times with a force of from 2 to 7. The daily variation was also here very pronounced, the average time of maximum flow occurring about $5^h\ 56^m$ after the moon's transit. At 65 and 130 fathoms depth the current, at three of the stations occupied, was north-westerly; at one south-easterly. The velocity at 130 fathoms was greater than at 65 fathoms, and greater at the surface than at 15 and 30 fathoms.

At all of the three stations between Grenada and Trinidad tidal action was observed, with deflections due to local influences.

The passage between Santa Lucia and St. Vincent appears to be in the line of the equatorial stream. At each of the five stations in this passage tidal action was pronounced, the currents setting in and out of the Caribbean Sea at some depth. The daily variation in this passage reaches a maximum at about $6^h\ 3^m$ after the moon's transit, and a minimum when the moon is on the meridian. The currents entering the Caribbean Sea through this passage are but 100 fathoms in depth, but there is probably an almost equal volume flowing out below that depth.

Between the Windward Islands the currents flow generally westward, but tidal action is everywhere apparent.

To the east of Desirade the currents at all observed depths have a northerly direction, fluctuating between about N. E. by E. to N. W. by N.

In the eastern part of the Anegada Passage the surface current flows into the Caribbean Sea in directions varying between S. S. W. and S. E., but the submarine current down to 130 fathoms flows in a direction lying between north and east.

In the more western part of the passage the currents are more complex, apparently on account of the greater variations in depth in the vicinity of the station occupied.

In the Mona Passage no regular currents were perceptible. Between Mona and Puerto Rico the currents observed set out of the Caribbean Sea, varying in direction from about W. by N.

to E. N. E., except at 65 fathoms depth, where there appeared to be an inward flow. On the western side of the passage, near Santo Domingo, the direction of the currents was between S. S. E. and S. W. by W. But few observations could be taken on account of unfavorable weather.

In the Windward Passage, on the western side the currents from the surface down to 130 fathoms set in the directions lying in the S. E. quadrant, and at 200 fathoms the direction changed to W. by S. On the eastern side the surface current varied between E. N. E. and E. S. E., with about ½ knot velocity. Variations in the direction similar in extent characterized also the sub-surface currents in the middle and on the eastern side of the passage.

The average of the observations at these three stations gives but a small volume of water passing in either direction.

In the old Bahama Channel, at the station north of Cayo Romano (island off the north coast of Cuba) the currents at and near the surface set south of east; at 65 fathoms, however, the direction varies from about N. W. to E. The deeper current of great volume flowed continually to the north of west with a velocity of over 1½ knots at depths of 130 and 200 fathoms.

Outside the Bahamas, to the north of Great Abaco, a slight current flows about N. W. on the surface and down to 30 fathoms; at 65 fathoms depth the direction changes to a point more westerly, and at 130 fathoms to a point more easterly than the set of the surface current. The maximum in the daily variation at this station occurs about 12^h after the moon's transit.

The observations so far as completed by Lieutenant Pillsbury furnish the most valuable data we have at present concerning the Gulf Stream, and it is hoped that further investigation and the analytical treatment of these observations will clearly develop the dynamic laws involved and lead us to a correct theory of current phenomena in general.

Tidal Phenomena.

The causes for many of the inequalities in the tidal elements observed at different places have not yet been satisfactorily explained. The phenomena are dependent on many purely terrestrial conditions. While we are able to ascertain with tolerable accuracy from certain constants, derived from observation, the times and heights of the tides, the problem to compute theoretically the tides of an ideal ocean of known depth and configuration remains still unsolved. According to Ferrel our present knowledge of tidal phenomena is comparable to that possessed 2,000 years ago of the science of astronomy.

Temperature of the Sea.

The temperature of sea water had already been observed by Ellis, in 1749, in the Atlantic, and subsequent expeditions have furnished a great number of temperature observations in various seas and for various depths. The diversity of instruments and of methods employed by the earlier observers, and the faulty methods of recording, have made the uniform reduction of many of these observations difficult or impossible. The most complete and valuable collection of these older observations up to 1868, with an account of the instruments and methods used by each observer, was published by Prestwich, in 1876, in the Philosophical Transactions, Vol. 165.

With the advent of the great scientific expeditions, which were supplied with modern and refined instruments, our knowledge of the thermal conditions of the sea has progressed immensely, and we are now able to construct charts of all the oceans, showing the distribution of the isotherms with considerable accuracy.

The annual average surface temperature has been found higher in the Indian Ocean than in either the Atlantic or Pacific ; the North Atlantic is slightly warmer than the North Pacific, but the South Pacific is warmer than the South Atlantic ; this holds generally good also for the temperatures between surface and bottom.

The temperature generally decreases more or less rapidly from the surface down to about 500 fathoms, at which depth it is quite uniformly between 39° and 40° F. From that depth it decreases slowly towards the bottom: in the Polar seas to between 27° and 28° F.; in the middle and higher latitudes of the northern hemisphere and at depths of 2,000 to 3,000 fathoms, to between 34° and 36° F.; at the equator and in southern latitudes it remains in the neighborhood of 32° F.

The low temperatures at the bottom are thought to be due to a steady but slow circulation of water from the Polar seas towards the equator, and, where the circulation is most free and unobstructed, as in the South Atlantic, South Pacific and Indian Ocean, the bottom temperature is slightly lower than in the North Atlantic and North Pacific, both of which are connected with the Polar Sea by comparatively narrow and shallow straits.

The theory of this circulation from the Polar seas is greatly strengthened by the facts appearing from the investigation of the bathymetric isotherms in inclosed seas, i. e., seas which are separated from the deep oceans by submarine barriers. In such seas the temperature decreases slowly from the surface down to the depth of the barrier, and from there on remains constant to the bottom.

The influence of currents on the surface temperature is very marked, cold currents bending the isothermal lines towards the equator, and warm currents bending them towards the poles. The seasonal changes in surface temperatures are considerable, being the least in the tropical zones.

In the *Atlantic Ocean* the maximum surface temperature lies near the coast of South America, between Para and Cayenne, and another maximum occurs near the west coast of Africa, between Freetown and Cape Coast Castle.

The *Pacific Ocean* shows the peculiarity that the surface temperatures on the western side are lower than those on the eastern side. Between 45° N. and 45° S. the temperature does not fall below 50°, but between those parallels and the poles it remains most always below that figure.

The warmest water is found in the *Red Sea* where the surface temperature has been recorded as high as 90°. North of the equator the mean annual temperature is considerably above 80°, but south of it, to about the parallel of 25°, it varies from 80° to 70°.

Chemical Composition, Salinity and Density of Sea Water.

In this branch of inquiry great progress has been made, and sea water is now known to contain at least 32 elementary bodies. Its chief constituents are found to consist of the chlorides and sulphates of sodium, magnesium, potassium and calcium. It also contains air and carbonic acid.

The salinity and density of sea water have been investigated very thoroughly, particularly in the Atlantic. As the salinity of the sea water is an index of its density, changes in the former naturally affect the latter. The salinity has been found generally to decrease in the neighborhood of coasts, where rivers discharge their water into the sea, and it is a maximum in the trade zones, and a minimum in the equatorial rain belt. The salinity is

12

affected by the degree of evaporation and by the frequency of rainfall, and is now recognized as an important factor in the biologic conditions of the sea.

Of the three great oceans, the Atlantic, with a salinity of 3.69 per cent., shows a slight preponderance over that of the Pacific and Indian Ocean, whose average salinity is 3.68 and 3.67, respectively.

In the trade belts the great evaporation augments the salinity, and hence, also, the density, and in the polar zones the formation of ice brings about the same result, though in a lesser degree. In the equatorial calm region the frequent rainfall diminishes salinity and density through the dilution of the salt water. Density and salinity are thus in a certain degree subject to seasonal changes.

In the *Atlantic* the density increases in general from the higher latitudes towards the equator, but the maxima are separated by a zone of lesser density. The maximum in the North Atlantic ocean is found between the Azores, the Canaries and the Cape Verde Islands, and the minimum between the equator and 15° N.

In the South Atlantic two maxima occur, one to the north of Trinidad, and the other near St. Helena and between that island and Ascension.

Taking pure water at 4° C. for unity, the maximum density in the Atlantic is 1.0275 and in the Pacific, 1.0270.

In the *North Pacific* the maximum density occurs between 30° and 31° N., and the minimum in about 7½° N., in the equatorial counter current, where it was found as low as 1.02485.

In the *South Pacific*, which has a slightly greater density than the North Pacific, the maximum has been found in the vicinity of the Society Islands.

The density of the waters of the *Indian Ocean* is not yet as well known as that of the Atlantic and Pacific, but the results ascertained indicate a lesser density in its northern part, with a maximum in the region between 20° and 36° S. and long. 60° to 80° E.

In the vicinity of Java and Sumatra, probably on account of the extreme humidity of the atmosphere and of frequent rainfall, the density has been found as low as 1.0250.

In regard to the density of the water at various depths, it has been ascertained that as a general rule it decreases from the surface down to about 1,000 fathoms, after which it increases again slowly to the bottom. In the equatorial calm regions, however, where the heavy rains dilute the surface water, the density decreases from the surface down to between 50 and 100 fathoms, after which it follows the law found for other parts of the ocean. The bottom densities of the South Atlantic and Pacific have been found about alike, varying only from 1.02570 to 1.02590 ; those of the North Atlantic, however, show a greater value, varying from 1.02616 to 1.02632.

GREATEST DEPTHS OF THE OCEANS.

ATLANTIC.—Rejecting some of the earliest soundings as untrustworthy, the greatest known depth in the North Atlantic is to the north of the island of Puerto Rico, in about latitude 19° 39′ N., longitude 66° 26′ W., found by the C. S. S. Blake, Lieut. Commander Brownson, U. S. N., in 1882–83, 4,561 fathoms.

The deepest known spot in the South Atlantic is 3,284 fathoms, in about latitude 19° 55′ S., longitude 24° 50′ W., sounded by the U. S. S. Essex, Commander Schley, in 1878.

The general run of the soundings indicates that greater depressions exist nearer the western than in the eastern or middle part of the Atlantic, North and South.

PACIFIC.—In the North Pacific the greatest depression has been found by the U. S. S. Tuscarora, Commander Geo. E. Belknap, U. S. N., in 1874, 4,655 fathoms, in latitude 44° 55′ N., longitude 152° 26′ E. The next deepest sounding in the North Pacific was located by the Challenger in 1875, 4,475 fathoms, in latitude 11° 24′ N., longitude 143° 16′ E. As in the Atlantic, the greater depths appear to exist in the western part and particularly off the coasts of Japan.

In the South Pacific the greatest depths were supposed, up to a recent period, to be in the eastern part. Within the last two years, however, the British surveying vessel Egeria has discovered greater depressions in the western part of the South Pacific, one spot sounding 4,430 fathoms in latitude 24° 37′ S., longitude 175° 08′ W., and another, 12 miles farther south, 4,298 fathoms.

INDIAN OCEAN.—In this ocean the greatest depths appear to exist to the north and west of the Australian continent, where there are more than 3,000 fathoms in a number of widely separated spots, indicating a depressed area of considerable extent.

In the most southerly part of the Indian Ocean, or rather in the

Antarctic region, the Challenger obtained, in 1874, a maximum depth of 1,673 fathoms, in latitude 65° 42′ S., longitude 79° 49′ E.

Arctic Ocean.—The greatest depth was sounded by the Sofia in 1868, 2,650 fathoms, in latitude 78° 05′ N., longitude 2° 30′ W.

In the minor seas the maximum depths so far as ascertained are :

Caribbean Sea	3,452 fms.,	south of Great Cayman.
Gulf of Mexico	2,119 "	(Sigsbee Deep).
Mediterranean	2,170 "	
North Sea	375 "	
Baltic	178 "	
China Sea	2,100 "	
Coral Sea	2,650 "	
Sulu Sea	2,550 "	
Celebes Sea	2,600 "	
Banda Sea	2,800 "	

January, 1889.

REPORT—GEOGRAPHY OF THE AIR.

By A. W. Greely.

In presenting to the National Geographic Society a summary of geographic advance as regards the domain of the air, the Vice-president finds a task somewhat difficult. The traveler passes from the east to the west coast of Africa, and his very efforts to struggle across that great continent, impress in his memory an abiding picture of the physical features of the country over which he has passed, and of the distribution of plants and animal life. So, too, a vessel sails from one coast to another, casting here and there a sounding lead, from which measurements it is possible to give quite a definite idea of the relief features of the bottom of the sea.

Small as are the traces which serve to indicate the character of the sea bottom, yet they are infinitely greater than those which enable us to give a description of the air. Atmospheric disturbances are so vast, and their action is so rapid, that it requires the attentive care of thousands of observers before one can well hope to draw the roughest figure of a passing storm. To note changes in the force and direction of the wind, to note the depth of the rain, the increase and decrease of temperature and the varying changes of aqueous vapor, either in visible or invisible form, requires millions of careful, systematic observations, and then when these are made, the task of collating, elaborating and discussing them seems almost too great for any man. Fortunately the value of meteorological work has impressed itself not only upon governments, which have assisted liberally by appropriations and organization, but yet more upon the isolated observer, thousands of whom over the face of the earth give of their time and labor, and add their mite to the wealth of universal knowledge.

In connection with all great physical questions, there is at times a tendency to application to special phases somewhat to the exclusion of others. While it can hardly be said that scientific and theoretical discussion of meteorology has been unduly neglected during the past year, yet it is evident that the greatest activity of meteorologists has been devoted to climatological investigation, and compilations of this character have been particularly numerous during the past year—not in the United States and Europe alone, but throughout the whole world.

The growing practical importance of meteorological researches has been lately evidenced perhaps in no more striking way than in the establishment in Brazil of a most extensive meteorological service, created by a decree of the Imperial government on April 4, 1888. A central meteorological institute, under the Minister of Marine, is to be the centre for meteorological, magnetic and other physical researches, and observations are to be made at all marine and military establishments in the various provinces, on the upper Amazon, in Uruguay, and on all subsidized government steamers. This service should soon be fruitful in results, as the meteorology of the interior of Brazil is almost absolutely unknown.

Another vast scheme has originated in Brazil in the Imperial Observatory of Rio Janeiro. Señor Cruls, its director, contemplates a dictionary of the climatology of the earth, giving monthly means and extremes of pressure, temperature, rainfall, wind, etc. This scheme, of course, can be successful only by international co-operation. The United States Signal Service has pledged its aid as regards this country.

The former tendency among Russian meteorologists to devote their greatest energies to climatological compilations has gradually given way to other practical work in connection with weather and storm predictions, as shown by the institution by the Russian government of a system of storm-warnings for the benefit of vessels navigating the Black Sea.

Blanford has put forth an important paper, which partially elucidates the very intricate question of diurnal barometric changes, particularly bearing on the relation of the maximum pressure to critical conditions of temperature, cloudiness and rainfall. The question viewed in a negative light by Lamont, as to whether the maximum barometric pressure could be attributed to the greatest rate of increase in the temperature of the air, due, it is supposed, to the reactionary effect of the heated and expanding air, has been re-examined by Blanford, whose conclusions are somewhat in favor of this theory.

S. A. Hill has treated of the annual oscillation of pressure, so noticeable in India, and in so doing has investigated the changes of pressure for three levels, up to a height of 4500 meters. The reduction of monthly barometric means at high levels, having regard to the vertical distribution of temperature, shows a double oscillation in the annual curve at the level of Leh, which becomes a single one at the height of 4500 meters, while this is substantially the reverse of the oscillation observed below.

The subject is also treated in another way by Mr. Hill, through analysis of normal monthly means for all India, whereby he succeeds in presenting a formula, the first periodic terms of which represent the two principal factors of the oscillation.

Mr. Hill has also discussed elaborately the anomalies in the winds of northern India in their relation to the distribution of barometric pressure. The anomalies are:—(1) in the hot season the wind direction frequently shows no relation to the barometric gradient; (2) the winds over the plains show little or no relation to pressure gradients, but an obvious one to temperature, being greatest where the temperature is highest.

It is pointed out as highly probable that the copious snowfalls of the late winter in the northwest Himalayas not only produce low temperatures on the Himalayan ranges, but subsequently cause dry northwesterly winds over northern and western India, and on this supposition, reliable forecasts of the character of the coming rainy monsoons have been made for a number of years. Convection currents between upper and lower air strata, it is suggested by Koppen, explain diurnal variations in wind velocity and direction. At low stations the maximum velocity occurs at the time of the highest temperature, while at high stations the reverse obtains. Hill has examined into an important point connected with this subject, that is, the great local differences in the vertical variation of temperature. Hill concludes by saying that high pressures at low levels are the result of low temperatures, and in connection with the fact that wind directions are largely influenced by the irregular distribution of pressure at high levels, it is more important to know the abnormal variations of pressure at the highest hill stations in India than those in the plains.

Overbeck has lately published a paper on the apparent motions of the atmosphere, in which he clearly and admirably outlines the treatment of the dynamics of the air by his predecessors. He comments on the mode of treatment of Ferrel, as well as those of Guldberg and Mohn. Overbeck then sets forth his own method, and elaborately discusses the influence of the earth's rotation with reference to the resistances which oppose the motion of the atmosphere. He touches on the effect produced by rapidly moving fluid entering fluid at rest, the development of discontinuous (so called by Helmholtz) currents, the tendency of parallel currents of unequal velocities towards similar velocities, the effect of friction arising from contiguous currents of different velocities, upon the coefficient of friction, of the temperature distribution over the surface of the earth, etc. He derives three very simple expressions for the motions of the air; the first giving the velocity in a vertical direction at any point, in terms of latitude, and a constant and factor depending on the distance of the point above the surface of the earth. The other expressions give the velocities in a north or south direction, and in an east or west direction, also in terms of constants and latitude. The velocity when charted from Overbeck's equations indicate an ascending vertical current from the equator to 35° north, and thence a descending current to the pole. The meridional current at the equator and pole are zero, and have a maximum value at latitude 45°.

Ciro Ferari, from long and important investigations of thunder-storms, shows that these phenomena invariably attend motionless areas of low pressure, and believes the surest elements for predicting such storms will be found to be the peculiarities in distribution of temperature and absolute humidity. He observes that the storm front invariably tends to project itself into the regions where the humidity is greatest, and that hail accompanies rapidly moving storms of deep barometric depression. Ferari considers the chief causes of thunder storms to lie in the connection of high temperature and high humidity. Grossman believes that ascending moist-laden currents are the cause of thunder storms, and hence they are most frequent when the temperature diminution with altitude is very great, so that the over-heating of the lower air strata in the warmest part of the day is the cause of the primary maximum of thunder-storm frequency.

Abercromby and Hildebrandsson have renewed their recommendations for a re-classification of clouds in ten fundamental types, in which the first part of the compound name, such as cirro-stratus, cirro-cumulus, etc., is to be in a measure indicative of the height of a cloud.

Hildebrandsson has charted the differences of monthly means of air pressure for January, 1874 to 1884. In January, 1874, the values at nearly all the stations in the Northern Hemisphere, were plus, and those in the Southern, minus. It is to be hoped that such general discussions of this important meteorological element may be continued.

General A. Von Tillo has determined, by means of the planimeter, the distribution of temperature and pressure from Teisserenc de Bort's charts. The mean pressure over the Northern Hemisphere for January, he finds to be 29.99 inches (761.7 millimeters), and the temperature 46°.9 (8.3 C.) ; in July, 29,806 (758.5 mm.) and 72°.7 (22°.6 C.). In Russia he finds an increase of one millimeter of pressure to correspond with a decrease of 1°.6 C. in temperature.

Doberck, after investigation of September typhoons at Hong Kong, attributes their appearance to the relatively low pressure then existing between Formosa and Lyon.

The valuable and elaborate investigation of American Storms, by Professor Elias Loomis has been completed. Loomis has thoroughly discussed barometric maxima and minima areas as presented by the maps of the Signal Service, from which it appears that these areas are in general elliptical, with the longest axis nearly twice that of the shortest in the high areas, while the difference is less in low areas. He has also investigated the winds relative to baric gradients, thus affording valuable data for proving various meteorological theories. Loomis' researches regarding the movement of maximum areas verify those which have been set forth from time to time in Signal Service publications ; wherefrom it appears that high areas have a more southerly movement than low areas.

Van Bezold has put forth a memoir on thermodynamics, while Helmholtz, Oberbeck, and Diro-Kitso have contributed valuable memoirs on motions caused by gravitation and the varying density of the air. These furnish meteorologists with important results as to the laws of fluid or gaseous motions. It is gratifying to Americans to note that the valuable results obtained by Ferrel in his many memoirs are confirmed by these later investigations.

Undoubtedly the most important meteorological event within the past year was the discontinuance, on January 1, 1888, of the system of International Simultaneous Meteorological reports inaugurated in accordance with the agreement of the conference at Vienna in September, 1873. As the charts of storm tracks, based on these observations, have been published by the United States Signal Service one year behind the date of the observations, the completion of this work in printed form for the general public should occur about December 31, 1888.

A few remarks in connection with this unparalleled set of observations may not be out of place. The congress which agreed upon this work, met in accordance with invitations issued by the Austrian Government in September, 1873. The co-operation decided upon at this congress took practical shape January 1, 1874, at which date one daily simultaneous report was commenced from the Russian and Turkish Empires, the British Islands, and the United States: the energetic co-operation of these nations being assured through Professor H. Wild for Russia; Professor A. Coumbary for Turkey; Mr. Robert H. Scott for Great Britain; and Bvt. Brig. General A. J. Meyer, for the United States. Concurrent action followed shortly after on the part of Austria, through Professor Carl Jelinek; Belgium through Professor E. Quetelet; Denmark through Capt. Hoffmeyer; France through Monsieurs U. J. Leverrier, Marie Davy, and St. Claire Deville; Algiers by General Farre; Italy by Professor Giovanni Cantoni; the Netherlands by Professor Buys Ballot; Norway by Professor H. Mohn; Spain by Professor A. Aquilar; Portugal by Professor F. de Silveira; Switzerland by Professor E. Plantamour; and the dominion of Canada by Professor G. T. Kingston. Within a year the average number of daily simultaneous observations made outside the limits of the United States increased to 214. Later, the co-operation of the Governments of India, Mexico, Australia, Japan, Brazil, Cape Colony, Germany, and Greece, was obtained, and also of many private observatories at widely separated points throughout the Northern Hemisphere.

In the sixteen years during which simultaneous meteorological observations were continued, reports were received from nearly fifteen hundred different stations, about one-half being from land stations, and the others from vessels of the navies and the merchant marine of the various countries.

The total number of storm centers, counting one for each 5-degree square over which the centre has been traced from the International Simultaneous observations of 1878 to 1887, inclusive, aggregates over forty-two thousand, an annual average of over four thousand two hundred. Less than $\frac{1}{25}$ of 1 per cent. of these storms occurred south of the parallel of 10°, and only $\frac{1}{4}$ of 1 per cent. south of the parallel of 15°. In marked contradistinction to this freedom of the equatorial regions from storms, there is to be noted the excessive prevalence of these phenomena between the parallels of 40° and 60°, north; in which regions substantially two-thirds of the storms of the Northern Hemisphere occurred; while between the parallels of 45° and 55°, north, 36 per cent. of the entire disturbances are recorded. The most remarkable belt of storm frequency on the Northern Hemisphere is that extending from the Gulf of Saint Lawrence westward to the extreme end of Lake Superior, as nearly 8 per cent. of all the storms of the Northern Hemisphere passed over this limited region; the maximum frequency (1.2 per centum) occurring over the 5-degree square northeastward of Lake Huron.

As regards longitudinal distribution, an unusually large proportion of storms prevailed between the 50th meridian and 105th meridian, west; 37 per cent. or one-third of all the storms of the Northern Hemisphere occurring within this region. A second belt of comparative storm frequency obtains from the meridian of Greenwich eastward to the 30th meridian; over which region 15 per cent. of the entire number of storms occurred.

Only four hundred, or less than 9 per cent. of the entire number of storms, entered the American continent from the Pacific ocean, while about thirteen hundred storms, excluding the West India hurricanes, passed eastward off of the American continent. Over nine hundred storms entered Europe from the Atlantic ocean, of which probably four hundred and fifty, or ten per cent. of the whole number recorded, were developed over the Atlantic ocean. Probably not thirty storms, or less than three per cent. of those which entered Europe from the Atlantic, crossed over the continents of Europe and Asia to the Pacific ocean. Fully two-thirds of the storms which enter Europe from the Atlantic are dissipated as active storm-centres before they reach the Asiatic frontier.

The tendency of great bodies of water, when surrounded wholly or largely by land, to generate storms or facilitate their development, is evident from the unusual prevalence of storms over the great lakes, the St. Lawrence bay and the Gulf of Mexico in North America; over the North and Baltic seas, Bay of Biscay and the Mediterranean in Europe; the Bay of Bengal, and over the China and Okhotsk seas.

Undoubtedly a considerable proportion of these storms are drawn towards these regions owing to the effect of evaporation upon the humidity and temperature of the superincumbent atmosphere, so that a very considerable proportion of the storms credited to these squares have not originated therein, but have been drawn up from neighboring quarters. This tendency is marked in North America, as storms pass over the lake region and St. Lawrence valley, whether they have originated in the Gulf of Mexico, along the central slope of the Rocky mountains in the United States, or further north in the Saskatchewan country. In like manner storms pass southeastward to the Mediterranean from the Bay of Biscay, and northeastward from the Atlantic ocean to the same sea, and then later show a very marked tendency to pass over the Black and Caspian seas.

This tendency of storms originating in diverse sections to move toward the lake regions in the United States, is very evident from the normal storm-track charts for April, May, June, August, November and December.

The opinion that gales rarely, if ever, occur upon the equator is confirmed by these storm-tracks. The most southern storm in the North Pacific ocean, developed in July, 1880, between the Island of Borneo and Mindanao, an excellent account of which is given by Père Mark Dechevrens, S. J., in the Bulletin Mensuelle of Zi-Ka-Wei Observatory. The most southern storm over the North Atlantic ocean, in November, 1878, was remarkable for its origin, duration, length of its path, and its enormous destruction of life and property. It was central on the 1st, as a violent tropical hurricane near Trinidad, the barometer being 29.05, the lowest ever recorded there, and, from its intensity and velocity, it is more than probable that it originated considerably to the eastward, and possibly somewhat to the southward of that island. The storm was described in the U. S. Monthly Weather Review for September, 1878.

The writer looks with considerable interest to the results which may follow from a discussion of the annual fluctuation of the atmospheric pressure as shown by the mean monthly pressures deduced from the ten years' International observations. As far as these means have been examined they show that the periodicity of atmospheric pressure is largely in accord with the results set forth in 1885 in The Report of the Lady Franklin Bay Expedition. The conviction expressed in that year is still adhered to—that, at no distant day, the general laws of atmospheric changes will be formulated, and that later, from abnormal *barometric departures* in remote regions may be predicted the general character of seasons in countries favorably located.

The success of long-time predictions of this class for India, has been set forth in a previous part of this report. It is believed that a further discussion of meteorological phenomena on a broad basis, by means of International Weather Charts, both in daily and monthly form, must eventually result in important and fundamental discoveries. It is gratifying to American pride to know that in this international task of outlining the geography of the air, the United States has liberally provided the labor and means for presenting these ten years' meteorological data in such tabular and geographical forms as to render them available for study by all.

Acknowledgment is due to Professor Thomas Russell, for valuable translations, especially from the German ; which translations have been of material value in preparing this report.

December, 1888.

REPORT—GEOGRAPHY OF LIFE.

C. Hart Merriam.

During the year now drawing to a close not a single work which I conceive to fall legitimately within the scope of the department of Geography of Life has appeared in any part of the world, so far as I am aware. It being manifestly impossible, then, to comply with the requirement of the By-law calling for a summary of the work of the year, I may be pardoned for digressing sufficiently to speak of what seems to be the *function* of this Society in its relations to biology.

The term '*Geography of Life*,' applied without limitation or qualification to one of the five departments of the Society is not only comprehensive, but is susceptible of different if not diverse interpretations. Indeed, without great violence it might be construed to comprehend nearly the whole domain of systematic botany, zoology, and anthropology. As a matter of fact, I believe it was intended to include everything relating directly to the distribution of life on the earth. Thus it would naturally embrace all sources of information which assign localities to species. Local lists and faunal publications of every kind would fall under this head, and also the narratives of travelers who mention the animals and plants encountered in their journeys. In the single branch of ornithology, about fifty per cent. of the current literature would have to be included. The most obvious objection to this comprehensiveness of scope is the circumstance that a mere bibliographic record of titles alone would fill a journal the size of the National Geographic Magazine.

Hence it may not be amiss to attempt a preliminary reconnoissance, with a view to what my friend Mr. Marcus Baker has recently defined as "a Survey of Class II, for Jurisdictional purposes." Let us seek therefore to run a boundary line about the territory we may fairly claim without trenching on the possessions of others.

Before doing this it becomes necessary to bear in mind certain facts and laws without a knowledge of which it is impossible to think intelligently on the subject. It is a matter of common observation that different groups of animals and plants inhabit different regions, even in the same latitude; that some forms are almost world wide in distribution; that others are restricted to very limited areas; that the ranges of very dissimilar species are often geographically coincident; and that, as a rule, animals inhabiting contiguous areas are more nearly related than those inhabiting remote areas. The recognition of these facts early led to the attempt to divide the surface of the earth, according to its animal life, into 'faunal' districts. By the term *fauna* is meant the sum of the animal life of a region.

A comparatively meagre supply of information is sufficient to indicate the principal faunal subdivisions of a country, but for mapping the exact boundaries of such areas a vastly greater and more precise fund of knowledge is necessary. The way in which such maps are prepared is by collecting all available authentic records of localities where the particular species has been found. This is done by compiling published records, by examining labels of specimens in various museums and private collections, and by work in the field. The data thus brought together are arranged on cards under authors and regions, and are tabulated under species. The localities are then indicated by colored spots on an outline map, the space surrounded by the spots being washed in with a paler tint of the same color. A separate map is devoted to each species.

Faunal maps are made by combining a large number of species maps. In making such combinations it is found, as a rule, that a considerable percentage of the species maps fall into certain well defined categories whose color patches are essentially coincident. The composite resulting from the coördination of these maps may be held to represent the natural faunal areas of a country. Several such areas may be characterized by the common possession of species not found elsewhere, and may be combined to constitute a faunal province; several provinces, a region; and several regions a realm or primary zoö-geographical division of the earth's surface.

Having ascertained the actual extent and limitations of the natural faunal districts, it remains to correlate the facts of distribution with the facts of physiography.

My own convictions are that the work of this Society in Geographic Distribution should be restricted to the generalization of results: that we should deal with philosophic deduction rather than with detailed observations and the tedious steps and laborious methods by which they are made available. Our aim should be to correlate the distribution of animals and plants with the physiographic conditions which govern this distribution, and to formulate the laws which are operative in bringing about the results we see. In other words, we are to study cause and effect in the relations of physiography to biology.

The kind of works meriting discussion in the annual report of the Vice-president of this section are such philosophic treatises as those of Humboldt, Dana, Agassiz, DeCandolle, Engler, Darwin, Huxley, Pelzeln, Sclater, Wallace, Baird, Verrill, Allen, Cope, and Gill. As it is seldom that more than one or two such works appear in any single year, there is likely to be ample opportunity for profitable discussion.

January, 1889.

ANNUAL REPORT OF THE TREASURER.

FOR THE YEAR ENDING DEC. 27, 1888.

THE TREASURER, in account with the NATIONAL GEOGRAPHIC SOCIETY.

1888.			
Dec. 27.	To cash received from life members		$100 00
	" " for annual dues year 1888		1025 00
			$1125 00
1888.			
Apr. 16.	By Cash—M. F. Peake & Co. (20 chairs)		$ 60 00
	" Paid Columbian University, rent of hall		20 00
Oct. 31.	" Paid Tuttle, Morehouse & Taylor, for printing and binding vol. I of Magazine	$ 190 56	
	" Norris Peters, for lithographing storm plates for Magazine	58 00	
	" Sundry expenses of Magazine	6 35	254 91
Dec. 27.	" Paid Cosmos Club, rent of hall		18 00
	" " for miscellaneous expenses:		
	" " " Printing	74 50	
	" " " Stationery	28 35	
	" " " Postage	29 15	
	" " " Sundries	13 39	145 39
Balance on hand (Bank of Bell & Co.)			626 70
			$1125 00

C. J. BELL,
Treasurer.

December 28, 1888.

To the National Geographic Society:

The undersigned, having been appointed an Auditing Committee to examine the accounts of the Treasurer for 1888, have the honor to make the following report:

We have compared the receipts with the official list of members and find complete agreement. We have compared the disbursements with the vouchers for the same and find them to have been duly authorized and correctly recorded. We have examined the bank account and compared the checks accompanying the same. We have compared the balance in the hands of the Treasurer as shown by the ledger ($626.70) with the balance as shown by the bank book ($644.70) and found them consistent, the difference being explained by the fact that a check for $18 drawn in favor of the Secretary of the Cosmos Club has not yet been presented for payment. We find the condition of the accounts entirely satisfactory.

Very respectfully,
S. H. KAUFMANN.
G. K. GILBERT.

ANNUAL REPORT OF THE SECRETARIES.

The first step toward the organization of the National Geographic Society was the circulation of the following invitation, on Jan. 10, 1888.

"Dear Sir: You are invited to be present at a meeting to be held in the Assembly hall of the Cosmos Club, Friday evening, January 13, at 8 o'clock, for the purpose of considering the advisability of organizing a society for the increase and diffusion of geographical knowledge.

Very respectfully yours,

Gardiner G. Hubbard,	Henry Mitchell,
A. W. Greely,	Henry Gannett,
J. R. Bartlett,	A. H. Thompson,

and others."

In response to this invitation 33 gentlemen met at the appointed place and time. The meeting was called to order by Prof. A. H. Thompson, who stated its objects and nominated Capt. C. E. Dutton as chairman. The formation of a geographic society was discussed by Messrs. Hubbard, Bartlett, Thompson, Mitchell, Kennan, Gannett, Merriam and Gore.

The following resolution, introduced by Prof. Thompson, was adopted:

Resolved, 1. As the sense of this meeting that it is both advisable and practicable to organize at the present time a geographic society in Washington;

2. That this society should be organized on as broad and liberal a basis in regard to qualifications for membership as is consistent with its own well being and the dignity of the science it represents.

3. That a committee of nine be appointed by the chairman to prepare a draft of a constitution and plan of organization, to be presented at an adjourned meeting to be held in this hall on Friday evening, January 20, 1888."

A committee was appointed by the chair, consisting of Messrs. Hubbard, Greely, Bartlett, Mitchell, Kennan, Thompson, Gore, Tittman and Merriam for formulating a plan of organization.

A subsequent meeting was held on January 20, at which it was decided to incorporate the society, and the same committee was continued to carry out that purpose. On January 27 the society was incorporated, the following gentlemen signing the certificate of incorporation:

Gardiner G. Hubbard,	J. W. Powell,
C. E. Dutton,	Henry Gannett,
O. H. Tittman,	A. H. Thompson,
J. Howard Gore,	A. W. Greely,
C. Hart Merriam,	Henry Mitchell,
J. R. Bartlett,	George Kennan,
Rogers Birnie, Jr.,	Marcus Baker,

Gilbert Thompson,

and upon the same day the first meeting of the society was held in the Assembly hall of the Cosmos club, when it was organized by the election of the following list of officers and the adoption of the by-laws:

President,

Gardiner G. Hubbard;

Vice-Presidents,

Herbert G. Ogden,	A. W. Greely,
J. R. Bartlett,	C. Hart Merriam,

A. H. Thompson;

Treasurer,

Charles J. Bell;

Recording Secretary,

Henry Gannett;

Corresponding Secretary,

George Kennan;

Managers,

Cleveland Abbe,	W. D. Johnson,
Marcus Baker,	Henry Mitchell,
Rogers Birnie, Jr.,	W. B. Powell,
G. Brown Goode,	James C. Welling.

The number of members who joined the society at its organization was 165. Since that date 45 have been elected to membership.

The society has lost one member by death during the year, Mr. James Stevenson.

The present number of members is 209.

The society has held 14 meetings, 13 of which have been devoted to the presentation of papers. It has published the first number of a magazine, copies of which have been distributed to the members of the society, to others interested in geography and to the geographic societies throughout the world for purposes of exchange.

The society has also undertaken the preparation of a Physical Atlas of the United States, upon which some progress has been made.

Very respectfully submitted,

HENRY GANNETT,
GEORGE KENNAN,
Secretaries.

Washington, D. C., December 28, 1888.

NATIONAL GEOGRAPHIC SOCIETY.

CERTIFICATE OF INCORPORATION.

This is to Certify that we whose names are hereunto subscribed, citizens of the United States, and a majority of whom are citizens of the District of Columbia, have associated ourselves together pursuant to the provisions of the Revised Statutes of the United States relating to the District of Columbia, and of an act of Congress entitled: "An Act to amend the Revised Statutes of the United States relating to the District of Columbia and for other purposes," approved April 23, 1884, as a Society and body corporate, to be known by the corporate name of the National Geographic Society, and to continue for the term of one hundred years.

The particular objects and business of this Society are: to increase and diffuse geographic knowledge; to publish the transactions of the Society; to publish a periodical magazine, and other works relating to the science of geography; to dispose of such publications by sale or otherwise and to acquire a library, under the restrictions and regulations to be established in its By-Laws.

The affairs, funds and property of the corporation shall be in the general charge of Managers, whose number for the first year shall be seventeen, consisting of a President, five Vice-Presidents, a Recording Secretary, a Corresponding Secretary, a Treasurer and eight other members, styled Managers, all of whom shall be chosen by ballot at the annual meeting. The duties of these officers and of other officers and standing committees, and their terms and the manner of their election or appointment shall be provided for in the By-Laws.

Gardiner G. Hubbard,	J. W. Powell,
C. E. Dutton,	Henry Gannett,
O. H. Tittman,	A. H. Thompson,
J. Howard Gore,	A. W. Greely,
C. Hart Merriam,	Henry Mitchell,
J. R. Bartlett,	George Keenan,
Rogers Birnie, Jr.,	Marcus Baker,

Gilbert Thompson.

OFFICERS.

1889.

President.

GARDINER G. HUBBARD.

Vice-Presidents.

HERBERT G. OGDEN.
GEO. L. DYER.
A. W. GREELY.
C. HART MERRIAM.
A. H. THOMPSON.

Treasurer.

CHARLES J. BELL.

Secretaries.

HENRY GANNETT. GEORGE KENNAN.

Managers.

CLEVELAND ABBE.
MARCUS BAKER.
ROGERS BIRNIE, JR.
G. BROWN GOODE.
C. A. KENASTON.
W. B. POWELL.
O. H. TITTMANN.
JAMES C. WELLING.

BY-LAWS.

ARTICLE I.

NAME.

The name of this Society is the "NATIONAL GEOGRAPHIC SOCIETY."

ARTICLE II.

OBJECT.

The object of this Society is the increase and diffusion of geographic knowledge.

ARTICLE III.

MEMBERSHIP.

The members of this Society shall be persons who are interested in geographic science. There may be three classes of members, active, corresponding and honorary.

Active members only shall be members of the corporation, shall be entitled to vote and may hold office.

Persons residing at a distance from the District of Columbia may become corresponding members of the Society. They may attend its meetings, take part in its proceedings and contribute to its publications.

Persons who have attained eminence by the promotion of geographic science may become honorary members.

Corresponding members may be transferred to active membership, and, conversely, active members may be transferred to corresponding membership by the Board of Managers.

The election of members shall be entrusted to the Board of Managers. Nominations for membership shall be signed by three active members of the Society; shall state the qualifications of the candidate; and shall be presented to the Recording Secretary. No nomination shall receive action by the Board of Managers until it has been before it at least two weeks, and no candidate shall be elected unless he receive at least nine affirmative votes.

ARTICLE IV.

OFFICERS.

The Officers of the Society shall be a President, five Vice-Presidents, a Treasurer, a Recording Secretary and a Corresponding Secretary.

The above mentioned officers, together with eight other members of the Society, known as Managers, shall constitute a Board of Managers. Officers and Managers shall be elected annually, by ballot, a majority of the votes cast being necessary to an election ; they shall hold office until their successors are elected ; and shall have power to fill vacancies occurring during the year.

The President, or, in his absence, one of the Vice-Presidents, shall preside at the meetings of the Society and of the Board of Managers ; he shall, together with the Recording Secretary, sign all written contracts and obligations of the Society, and attest its corporate seal ; he shall deliver an annual address to the Society.

Each Vice-President shall represent in the Society and in the Board of Managers, a department of geographic science, as follows:

Geography of the Land,
Geography of the Sea,
Geography of the Air,
Geography of Life,
Geographic Art.

The Vice-Presidents shall foster their respective departments within the Society ; they shall present annually to the Society summaries of the work done throughout the world in their several departments.

They shall be elected to their respective departments by the Society.

The Vice-Presidents, together with the two Secretaries, shall constitute a committee of the Board of Managers on Communications and Publications.

The Treasurer shall have charge of the funds of the Society, shall collect the dues, and shall disburse under the direction of the Board of Managers ; he shall make an annual report ; and his accounts shall be audited annually by a committee of the Society and at such other times as the Board of Managers may direct.

The Secretaries shall record the proceedings of the Society and of the Board of Managers ; shall conduct the correspondence of the Society ; and shall make an annual report.

The Board of Managers shall transact all the business of the Society, except such as may be presented at the annual meeting. It shall formulate rules for the conduct of its business. Nine members of the Board of Managers shall constitute a quorum.

ARTICLE V.

DUES.

The annual dues of active members shall be five dollars, payable during the month of January, or, in the case of new members, within thirty days after election.

The dues of members elected in November and December shall be credited to the succeeding year.

Annual dues may be commuted and life membership acquired by the payment of fifty dollars.

No member in arrears shall vote at the annual meeting, and the names of members two years in arrears shall be dropped from the roll of membership.

ARTICLE VI.

MEETINGS.

Regular meetings of the Society shall be held on alternate Fridays. from November until May, and excepting the annual meeting, they shall be devoted to communications. The Board of Managers shall, however, have power to postpone or omit meetings, when deemed desirable. Special meetings may be called by the President.

The annual meeting for the election of officers shall be the last regular meeting in December.

The meeting preceding the annual meeting shall be devoted to the President's annual address.

The reports of the retiring Vice-Presidents shall be presented in January.

A quorum for the transaction of business shall consist of twenty-five active members.

ARTICLE VII.

AMENDMENTS.

These by-laws may be amended by a two-thirds vote of the members present at a regular meeting, provided that notice of the proposed amendment has been given in writing at a regular meeting at least four weeks previously.

MEMBERS OF THE SOCIETY.

---

a., original members.
l., life members.
* Deceased.
In cases where no city is given in the address, Washington, D. C., is to be understood.

ABBE, PROF. CLEVELAND, *a. l.*,
Army Signal Office. 2017 I Street.

ABERT, S. T. (Sylvanus Thayer),
810 Nineteenth Street.

AHERN, JEREMIAH,
Geological Survey. 804 10th Street.

ALLEN, DR. J. A. (Joseph Asaph),
American Museum Natural History, New York.

APLIN, S. A., JR. (Stephen Arnold),
Geological Survey. 1513 R. Street.

ARRICK, CLIFFORD, *a.*,
Geological Survey. 1131 Fourteenth Street.

ASHBURNER, PROF. CHARLES A.,
Pa. Geol. Survey, Hamilton Bldg., Pittsburg, Pa.

ATKINSON, MISS E. S. (Emma Seccombe), *a.*,
Washington Normal School. 918 Massachusetts Avenue.

ATKINSON, W. R. (William Russum), *a.*,
Geological Survey. 2900 Q Street.

AYRES, MISS S. C. (Susan Caroline), *a.*,
Pension Office. 502 A Street SE.

BAKER, PROF. FRANK, *a.*,
Light House Board. 1315 Corcoran Street.

BAKER, MARCUS, *a.*,
Geological Survey. 1125 Seventeenth Street.

BALDWIN, H. L. (Harry Lewis), *a.*,
Geological Survey. 125 Sixth Street NE.

BARNARD, E. C. (Edward Chester), *a.*,
Geological Survey. 1715 G Street.

BARTLE, R. F. (Rudolph Francis),
947 Virginia Avenue SW.

BARTLETT, COMDR. J. R. (John Russell), U. S. N., *a.*,
Providence, R. I.

BASSETT, C. C. (Charles Chester), *a.*,
Geological Survey. 929 New York Avenue.

BELL, A. GRAHAM (Alexander Graham), *a.*,
1336 Nineteenth Street.

BELL, CHAS. J. (Charles James), *a.*,
1437 Pennsylvania Avenue. 1328 Nineteenth Street.

BIEN, JULIUS, *a.*,
139 Duane Street, New York, N. Y.

BIEN, MORRIS, *a.*,
Geological Survey. Takoma Park, D. C.

BIRNIE, CAPT. ROGERS, JR., U. S. A., *a.*,
Ordnance Office. 1341 New Hampshire Avenue.

BLAIR, H. B. (Herbert Buxton), *a.*,
Geological Survey. 1831 F Street.

BLODGETT, JAMES H. (James Harvey), *a.*,
Geological Survey. 1237 Massachusetts Avenue.

BODFISH, S. H. (Sumner Homer), *a.*,
Geological Survey. 58 B Street NE.

BOUTELLE, CAPT. C. O. (Charles Otis), *a.*,
Coast and Geodetic Survey.

BRAID, ANDREW, *a.*,
Coast and Geodetic Survey. 807 E. Cap. Street.

BRENT, L. D. (Lawrence Decatur),
Geological Survey. 1334 Q Street.

BREWER, H. G. (Harrison Gaston), *a.*,
Hydrographic Office. Meridian Avenue, Mt. Pleasant.

BREWSTER, WILLIAM,
Cambridge, Massachusetts.

BROWN, MISS E. V. (Elizabeth Virginia),
1312 S Street.

BURTON, PROF. A. E. (Alfred Edner), *a.*,
Massachusetts Institute of Technology, Boston, Mass.

CARPENTER, Z. T. (Zachary Taylor), *a.*,
1003 F. Street. 1009 Thirteenth Street.

CHAPMAN, R. H. (Robert Hollister), *a.*,
Geological Survey. 1207 L Street.

CHATARD, DR. THOS. M. (Thomas Marean), *a.*,
Geological Survey. 516 Park Avenue, Baltimore, Md.

CHRISTIE, PETER H. (Peter Harrison),
Geological Survey.

CLARK, A. HOWARD (Alonzo Howard),
National Museum. 1527 S Street.

CLARK, E. B. (Elias Buckner), *a.*,
Geological Survey. Laurel, Md.

COLVIN, VERPLANCK, *a.*,
Albany, New York.

COURT, E. E. (Emil Edward),
Hydrographic Office. 431 Q Street.

CUMMIN, R. D. (Robert Dodge), *a.*,
Geological Survey. 1710 I Street.

Curtis, W. E. (William Ellery), *a.*,
513 Fourteenth Street. 1424 Q Street.
Dall, Mrs. Caroline H. (Caroline Healey), *a.*,
1603 O Street.
Darwin, Chas. C. (Charles Carlyle), *a.*,
Geological Survey. 1907 Harewood Avenue, Le Droit Park.
Davidson, Prof. George, *a.*,
Coast and Geodetic Survey. San Francisco, Cal.
Davis, A. P. (Arthur Powell), *a.*,
Geological Survey. 314 M Street.
Davis, Mrs. A. P. (Elizabeth Brown Davis),
314 M Street.
Davis, Prof. Wm. M. (William Morris),
308 Walnut Street, Philadelphia, Pa.
Day, Dr. David T. (David Talbot),
Geological Survey. 621 Thirteenth Street.
Dennis, W. H. (William Hooper), *a.*,
Coast and Geodetic Survey. 12 Iowa Circle.
Diller, J. S. (Joseph Silas), *a.*,
Geological Survey. 1804 Sixteenth Street.
Douglas, E. M. (Edward Morehouse), *a.*,
Geological Survey. Takoma Park, D. C.
Dow, John M.,
Pacific Mail S. S. Co., Panama.
Duke, Basil,
Geological Survey. 457 C Street.
Dunnington, A. F. (Abner F.), *a.*,
Geological Survey. 504 A Street SE.
Durand, John,
16 Rue Littre, Paris.
Dutton, A. H. (Arthur Henry), *a.*,
Hydrographic Office. 1305 H Street.
Dutton, Capt. C. E. (Clarence Edward), U. S. A., *a.*,
Geological Survey. 2024 R Street.
Dyer, Lieut. G. L. (George Leland), U. S. N.,
Hydrographic Office. 1415 Twentieth Street.
*Dyer, G. W. (George Washington), *a.*,
1003 F Street. 1325 Vermont Avenue.
Edson, J. R. (Joseph Romanzo), *a.*,
1003 F Street. 1335 Corcoran Street.
Elliott, Lieut. W. P. (William Power), U. S. N., *a.*,
Navy Department. 1801 Q Street.
Fairfield, G. A. (George Albert), *a.*,
Coast and Geodetic Survey. 1418 Fifteenth Street.
Fairfield, Walter B. (Walter Brown), *a.*,
Coast and Geodetic Survey.
Fernow, B. E. (Bernhard Eduard), *a.*,
Department of Agriculture. 1704 Nineteenth Street.

FINLEY, LIEUT. J. P. (John Park), U. S. A., *a.*,
Army Signal Office. 1003 Twenty-fourth Street.

FISCHER, E. G. (Ernst George), *a.*,
Coast and Geodetic Survey. 436 New York Avenue.

FITCH, C. H. (Charles Hall), *a.*,
Geological Survey. 3025 N Street.

FLETCHER, L. C. (Louis Cass), *a.*,
Geological Survey. 1831 F Street.

FLETCHER, DR. ROBERT, *a.*,
Army Medical Musuem. The Portland.

FORD, W. C. (Worthington Chauncey), *a.*,
State Department. 1725 H Street.

GAGE, N. P. (Nathaniel P., *a.*,
Seaton School.

GANNETT, HENRY, *a.*,
Geological Survey. 1881 Harewood Avenue, Le Droit Park.

GANNETT, S. S. (Samuel Stinson), *a.*,
Geological Survey. 401 Spruce Street, Le Droit Park.

GILBERT, G. K. (Grove Karl), *a.*,
Geological Survey. 1424 Corcoran Street.

GILMAN, PRES. D. C. (Daniel Coit), *a.*,
Johns Hopkins University, Baltimore, Md.

GOODE, G. BROWN (George Brown), *a.*,
National Museum. Lanier Heights.

GOODE, R. U. (Richard Urquhart), *a.*,
Geological Survey. 1600 Sixteenth Street.

GOODFELLOW, EDWARD, *a.*,
Coast and Geodetic Survey. 7 Dupont Circle.

GORDON, R. O. (Rhome O.), *a.*,
Geological Survey. St. Asaph Junction, Va.

GRANGER, F. D. (Frank DeWolf),
Coast and Geodetic Survey.

GREELY, GEN. A. W. (Adolphus Washington), U. S. A., *a.*,
Army Signal Office. 1914 G Street.

GRISWOLD, W. T. (William Tudor), *a.*,
Geological Survey. 1715 G Street.

GULLIVER, F. P. (Frederic Putnam),
Geological Survey. 811 Ninth Street.

HACKETT, MERRILL, *a.*,
Geological Survey. 490 Maine Avenue.

HARRISON, D. C. (Dabney Carr), *a.*,
Geological Survey.

HASBROUCK, E. M. (Edwin Marble),
Geological Survey. 1625 Fourteenth Street.

HASKELL, E. E. (Eugene Elwin), *a.*,
Coast and Geodetic Survey. 1418 Fifteenth Street.

HAYDEN, LIEUT. E. E. (Edward Everett), U. S. N., *a.*,
Hydrographic Office. 1802 Sixteenth Street.

Heaton, A. G., (Augustus George),
1618 Seventeenth Street.

Henry, A. J. (Alfred Judson), *a.*,
Army Signal Office. 1404 S Street.

Henshaw, H. W. (Henry Wetherbee), *a.*,
Bureau of Ethnology. 13 Iowa Circle.

Herrle, Gustav, *a.*,
Hydrographic Office. 646 C Street NE.

Herron, W. H. (William Harrison), *a.*,
Geological Survey. 1008 H Street.

Hill, Geo. A. (George Andrews), *a.*,
Army Signal Office. 2148 Pennsylvania Avenue.

Hill, Prof. R. T. (Robert Thomas),
Austin, Texas.

Hinman, Russell,
Cincinnati, O. In care Van Antwerp, Bragg & Co.

Hodgkins, Prof. H. L. (Howard Lincoln), *a.*,
Columbian University. 1531 Ninth Street.

Hopkins, C. L. (Charles Linsley),
Department of Agriculture. 1443 Chapin Street.

Hornaday, W. T. (William Temple), *a.*,
National Museum. 405 Spruce Street, Le Droit Park.

Howell, E. E. (Edwin Eugene), *a.*,
48 Oxford Street, Rochester, N. Y.

Howell, D. J. (David Janney), *a.*,
939 F Street. Alexandria, Va.

Hubbard, Gardiner G. (Gardiner Greene), *a.*,
1328 Connecticut Avenue.

Iardella, C. T. (Charles Thaddeus), *a.*,
Coast and Geodetic Survey. 1536 I Street.

Jennings, J. H. (James Henry), *a.*,
Geological Survey. 822 H Street NE.

Johnson, A. B. (Arnold Burges), *a.*,
Treasury Department. 501 Maple Avenue, Le Droit Park.

Johnson, J. B.,
Howard University.

Johnson, S. P. (Stuart Phelps),
501 Maple Avenue, Le Droit Park.

Johnson, W. D. (Willard Drake), *a.*,
Geological Survey. 501 Maple Avenue, Le Droit Park.

Karl, Anton, *a.*,
Geological Survey. 1210 B Street SW.

Kauffmann, S. H. (Samuel Hay), *a.*,
1000 M Street.

Kenaston, Prof. C. A. (Carlos Albert), *a.*,
Howard University.

Kennan, George, *a.*,
1318 Massachusetts Avenue.

KENNEDY, GEORGE G., *l.*,
Roxbury, Mass.

KERR, M. B. (Mark Brickell), *a.*,
Geological Survey.

KIMBALL, E. F. (Edward Fenno),
411 Maple Avenue, Le Droit Park.

KIMBALL, S. I. (Sumner Increase), *a.*,
411 Maple Avenue, Le Droit Park.

KING, F. H.,
University of Wisconsin, Madison, Wis.

KING, PROF. HARRY, *a.*,
Geological Survey. 1319 Q Street.

KING, WILLIAM B.,
1328 Twelfth Street.

KING, MRS. W. B.,
1328 Twelfth Street.

KNIGHT, F. J. (Frederick Jay), *a.*,
Geological Survey. 744 Eighth Street.

KNOWLTON, F. H. (Frank Hall), *a.*,
National Museum.

KOCH, PETER, *a.*,
Bozeman, Mont.

LACKLAND, W. E. (William Eason), *a.*,
Geological Survey. 1305 Corcoran Street.

LEACH, BOYNTON,
Hydrographic Office. 2028 P Street.

LERCH, R. L. (Robert Lee), *a.*,
Hydrographic Office. 809 Twenty-first Street.

LINDENKOHL, ADOLPH, *a.*,
Coast and Geodetic Survey. 19 Fourth Street SE.

LINDENKOHL, HENRY, *a.*,
Coast and Geodetic Survey. 452 K Street.

LONGSTREET, R. L. (Robert Lee), *a.*,
Geological Survey. 1536 I Street.

LOVELL, W. H. (William Henry),
Geological Survey. 2410 Fourteenth Street.

McGEE, W J, *a.*,
Geological Survey. 1620 P Street.

McGILL, MISS MARY C.,
336 C Street.

McKEE, R. H. (Redick Henry), *a.*,
Geological Survey. 1753 Rhode Island Avenue.

McKINNEY, R. C. (Robert Christian), *a.*,
Geological Survey. 1120 Thirteenth Street.

MAHER, J. A. (James Arran), *a.*,
Johnson City, Tenn.

MANNING, VAN H., JR. (Van Hartrog),
Geological Survey, Branchville, Md.

Marindin, H. L. (Henry Louis),
Coast and Geodetic Survey. 1316 Rhode Island Avenue.

Marsh, Ens. C. C. (Charles Carleton), U. S. N., *a.*,
Naval Observatory. 926 Twenty-third Street.

Matthews, Dr. Washington, U. S. A., *a.*,
Army Medical Museum. 1262 New Hampshire Avenue.

Melville, Geo. W. (George White), *a.*,
Engineer in Chief, U. S. N. Navy Department. 1705 H Street.

Menocal, Civ. Eng. A. G. (Aniceto Garcia), U. S. N., *a.*,
Navy Department. 2012 Hillyer Place.

Merriam, Dr. C. Hart (Clinton Hart), *a.*,
Department of Agriculture. 1919 Sixteenth Street.

Mindeleff, Cosmos,
Bureau of Ethnology. 1408 Eleventh Street.

Mindeleff, Victor,
Bureau of Ethnology. 2504 Fourteenth Street.

Mitchell, Prof. Henry, *a.*,
18 Hawthorne Street, Roxbury, Mass.

Mosman, A. T. (Alonzo Tyler), *a.*,
Coast and Geodetic Survey.

Muldrow, Robert, *a.*,
Geological Survey. 1412 Fifteenth Street.

Murlin, A. E. (Arlington Elliott),
Geological Survey. 1550 Third Street.

Myers, Mrs. Ida. G. (Idalia Gilbert),
1008 I Street.

Natter, E. W. F. (Ernst Wilhelm Franz),
Geological Survey. 474 Pennsylvania Avenue.

Nell, Louis, *a.*,
Geological Survey. 1118 Virginia Avenue SW.

Niles, W. H.,
Massachusetts Institute of Technology, Boston, Mass.

Nordhoff, Charles, *a.*,
1731 K Street.

Ogden, H. G. (Herbert Gouverneur), *a.*,
Coast and Geodetic Survey. 1324 Nineteenth Street.

Parsons, F. H. (Francis Henry), *a.*,
Coast and Geodetic Survey. 210 First Street SE.

Patton, Pres. W. W. (William Weston), *a.*,
Howard University. 425 College Street.

Peale, Dr. A. C. (Albert Charles), *a.*,
Geological Survey. 1446 Stoughton Street.

Perkins, E. T., Jr. (Edmund Taylor), *a.*,
Geological Survey. 1831 F Street.

Penrose, R. A. F.,
Austin, Texas.

Peters, Lieut. G. H. (George Henry), U. S. N., *a.*,
Navy Department.

Peters, W. J. (William John), *a.*,
Geological Survey. 1831 F Street.

Pierce, Josiah, Jr.,
Geological Survey. 1829 G Street.

Powell, Major J. W. (John Wesley), *a.*,
Geological Survey. 910 M Street.

Powell, Prof. Wm. B. (William Bramwell), *a.*,
Franklin School Building. 1729 Twelfth Street.

Prentiss, Dr. D. W. (Daniel Webster), *a.*,
1101 Fourteenth Street.

Renshawe, Jno. H. (John Henry), *a.*,
Geological Survey. 1121 I Street.

Ricksecker, Eugene, *a.*,
Seattle, Washington Territory.

Riley, Dr. C. V. (Charles Valentine), *a.*,
Department of Agriculture. 1700 Thirteenth Street.

Ritter, H. P. (Homer Peter), *a.*,
Coast and Geodetic Survey. 1125 Seventeenth Street.

Roberts, A. C. (Arthur Carr), *a.*,
Hydrographic Office.

Russell, I. C. (Israel Cook), *a.*,
Geological Survey. 1754 Corcoran Street.

Sargent, Prof. C. S. (Charles Sprague), *a.*,
Brookline, Massachusetts.

Schley, Com. W. S. (Winfield Scott), U. S. N., *a.*,
Navy Department. 825 Vermont Avenue.

Scudder, Sam. H. (Samuel Hubbard), *a.*,
Cambridge, Massachusetts.

Shaler, Prof. N. S. (Nathaniel Southgate), *a.*,
Cambridge, Massachusetts.

Siebert, J. S. (John Selmar),
Hydrographic Office. 330 Spruce Street, Le Droit Park.

Smith, Edwin, *a.*,
Coast and Geodetic Survey. 2024 Hillyer Place.

Smith, Middleton, *a.*,
Army Signal Office. 1616 Nineteenth Street.

Sommer, E. J. (Ernest Julius), *a.*,
Coast and Geodetic Survey. 330 A Street SE.

Stein, Robert,
Geological Survey.

Stejneger, Leonhard, *a.*,
National Museum.

Stockton, Lt. Comdr. C. H. (Charles Hubert), U. S. N., *a.*,
Navy Department. 1828 I Street.

Sutton, Frank,
Geological Survey. 928 K Street.

Thomas, Miss Mary von E. (Mary von Erden), *a.*,
Coast and Geodetic Survey. 229 New Jersey Avenue SE.

THOMPSON, PROF. A. H. (Almon Harris), *a.*,
Geological Survey.

THOMPSON, GILBERT, *a.*,
Geological Survey. 1448 Q Street.

THOMPSON, LAURENCE, *a.*,
Box 380, Seattle, Washington Territory.

THOMPSON, LIEUT. R. E. (Richard Edward), U. S. A., *a.*,
War Department. 2011 N Street.

TITTMANN, O. H. (Otto Hilgard), *a.*,
Coast and Geodetic Survey. 1019 Twentieth Street.

TOWSON, R. M. (Richard Mathew), *a.*,
Geological Survey. 824 Thirteenth Street.

TRENHOLM, HON. WM. L. (William Lee), *a.*,
American Surety Company, 160 Broadway, N. Y.

TWEEDY, FRANK, *a.*,
Geological Survey.

URQUHART, CHAS. F. (Charles Fox), *a.*,
Geological Survey. 1600 Sixteenth Street.

VASEY, DR. GEORGE, *a.*,
Department of Agriculture. 2012 Fourteenth Street.

VINAL, W. I. (Washington Irving), *a.*,
Coast and Geodetic Survey. 152 D Street SE.

VON HAAKE, ADOLPH,
Post Office Department. 1215 L Street.

WALCOTT, C. D. (Charles Doolittle), *a.*,
Geological Survey. 418 Maple Avenue, Le Droit Park.

WALLACE, H. S. (Hamilton Stone), *a.*,
Geological Survey. 2118 G Street.

WARD, LESTER F. (Lester Frank), *a.*,
Geological Survey. 1464 Rhode Island Avenue.

WEED, WALTER H. (Walter Harvey), *a.*,
Geological Survey. 825 Vermont Avenue.

WEIR, J. B. (John Bradford), *a.*,
1602 L Street.

WELLING, DR. J. C. (James Clarke), *a.*,
1302 Connecticut Avenue.

WHITE, DR. C. A. (Charles Abiathar), *a.*,
Geological Survey. 312 Maple Avenue, Le Droit Park.

WHITE, DR. C. H. (Charles Henry), U. S. N., *a.*,
Navy Department.

WHITING, HENRY L. (Henry Laurens),
Coast and Geodetic Survey. West Tisbury, Mass.

WILDER, GEN. J. T. (John Thomas), *a. l.*,
Johnson City, Tenn.

WILDER, MISS MARY,
Johnson City, Tenn.

WILLIS, BAILEY, *a.*,
Geological Survey. 1512 R Street.

WILLIS, MRS. BAILEY (Altona H. Grinnell),
1512 R Street.

WILSON, A. E. (Adolphus Irwin),
Geological Survey. 931 G Street.

WILSON, H. M. (Herbert Michael), *a.*,
Geological Survey. Cosmos Club.

WILSON, THOMAS,
National Museum. 1218 Connecticut Avenue.

WINSTON, ISAAC,
Coast and Geodetic Survey. 1325 Corcoran Street.

WOODWARD, R. S. (Robert Simpson), *a.*,
Geological Survey. 1804 Columbia Road.

YARROW, DR. H. C. (Harry Crécy), U. S. A., *a.*,
Army Medical Museum. 814 Seventeenth Street.

YEATES, CHAS. M. (Charles Marion), *a.*,
Geological Survey. 1304 R Street.

Vol. I. No. 3.

THE

NATIONAL GEOGRAPHIC MAGAZINE.

NATIONAL GEOGRAPHIC SOCIETY
INCORPORATED
A.D.1888.

PUBLISHED BY THE

NATIONAL GEOGRAPHIC SOCIETY.

WASHINGTON, D. C.

Price 50 cents.

CONTENTS.

JULY, 1889.

PRESS OF TUTTLE, MOREHOUSE & TAYLOR, NEW HAVEN, CONN.

THE

NATIONAL GEOGRAPHIC MAGAZINE.

Vol. I. 1889. No. 3.

THE RIVERS AND VALLEYS OF PENNSYLVANIA.*

By William Morris Davis.

"In Faltensystemen von sehr hohem Alter wurde die ursprüngliche Anordnung der Langenthäler durch das Ueberhandnehmen der transversalen Erosionsfurchen oft ganz und gar verwischt."

Löwl. Petermann's Mittheilungen, xxviii, 1882, 411.

CONTENTS.

* The substance of this essay was presented to the Society in a lecture on February 8th, 1889, but since then it has been much expanded.

PART FIRST. *Introductory.*

1. *Plan of work here proposed.*—No one now regards a river and its valley as ready-made features of the earth's surface. All are convinced that rivers have come to be what they are by slow processes of natural development, in which every peculiarity of river-course and valley-form has its appropriate cause. Being

fully persuaded of the gradual and systematic evolution of topographic forms, it is now desired, in studying the rivers and valleys of Pennsylvania, to seek the causes of the location of the streams in their present courses; to go back if possible to the early date when central Pennsylvania was first raised above the sea and trace the development of the several river systems then implanted upon it from their ancient beginning to the present time.

The existing topography and drainage system of the State will first be briefly described. We must next inquire into the geological structure of the region, follow at least in a general way the deformations and changes of attitude and altitude that it has suffered, and consider the amount of denudation that has been accomplished on its surface. We must at the same time bear in mind the natural history of rivers, their morphology and development; we must recognize the varying activities of a river in its youth and old age, the adjustments of its adolescence and maturity, and the revival of its decrepit powers when the land that it drains is elevated and it enters a new cycle of life. Finally we shall attempt to follow out the development of the rivers of Pennsylvania by applying the general principles of river history to the special case of Pennsylvania structure.

2. *General description of the topography of Pennsylvania.*— The strongly marked topographic districts of Pennsylvania can hardly be better described than by quoting the account given over a century ago by Lewis Evans, of Philadelphia, in his "Analysis of a map of the middle British colonies in America" (1755), which is as valuable from its appreciative perception as it is interesting from its early date. The following paragraphs are selected from his early pages:

"The land southwestward of Hudson's River is more regularly divided and into a greater number of stages than the other. The first object worthy of regard in this part is a rief or vein of rocks of the talky or isinglassy kind, some two or three or half a dozen miles broad; rising generally some small matter higher than the adjoining land; and extending from New York city southwesterly by the lower falls of Delaware, Schuylkill, Susquehanna, Gun-Powder, Patapsco, Potomack, Rapahannock, James river and Ronoak. This was the antient maritime boundary of America and forms a very regular curve. The land between this rief and the sea and from the Navesink hills southwest . . . . . may be denominated the Lower Plains, and consists of soil washt down from above and sand accumulated from the ocean. Where these plains are not penetrated by rivers, they are a white sea-sand, about twenty feet deep and perfectly barren, as no mixture of soil helps to enrich them. But the borders of the rivers, which descend from the uplands, are rendered fertile by the soil washt down with the floods and mixt with the sands gathered from the sea. The substratum of sea-mud, shells and other foreign subjects is a perfect confirmation of this supposition. And hence it is that for 40 or 50 miles inland and all the way from the Navesinks to Cape Florida, all is a perfect barren where the wash from the uplands has not enriched the borders of the rivers; or some ponds and defiles have not furnished proper support for the growth of white cedars. . . . . .

"From this rief of rocks, over which all the rivers fall, to that chain of broken hills, called the South mountain, there is the distance of 50, 60 or 70 miles of very uneven ground, rising sensibly as you advance further inland, and may be denominated the Upland. This consists of veins of different kinds of soil and substrata some scores of miles in length; and in some places overlaid with little ridges and chains of hills. The declivity of the whole gives great rapidity to the streams; and our violent gusts of rain have washt it all into gullies, and carried down the soil to enrich the borders of the rivers in the Lower Plains. These inequalities render half the country not easily capable of culture, and impoverishes it, where torn up by the plow, by daily washing away the richer mould that covers the surface.

"The South mountain is not in ridges like the Endless mountains, but in small, broken, steep, stoney hills; nor does it run with so much regularity. In some places it gradually degenerates to nothing, not to appear again for some miles, and in others it spreads several miles in breadth. Between South mountain and the hither chain of the Endless mountains (often for distinction called the North mountain, and in some places the Kittatinni and Pequélin), there is a valley of pretty even good land, some 8, 10 or 20 miles wide, and is the most considerable quantity of valuable land that the English are possest of; and runs through New Jersey, Pensilvania, Mariland and Virginia. It has yet obtained no general name, but may properly enough be called Piemont, from its situation. Besides conveniences always attending good land, this valley is everywhere enriched with Limestone.

"The Endless mountains, so called from a translation of the Indian name bearing that signification, come next in order. They are not confusedly scattered and in lofty peaks overtopping one another, but stretch in long uniform ridges scarce half a mile perpendicular in any place above the intermediate vallies. Their name is expressive of their extent, though no doubt not in a literal sense. . . . . . The mountains are almost all so many ridges with even tops and nearly of a height. To look from these hills into the lower lands is but, as it were, into an ocean of woods, swelled and deprest here and there by little inequalities, not to be distinguished one part from another any more than the waves of the real ocean. The uniformity of these mountains, though debarring us of an advantage in this respect, makes some amends in another. They are very regular in their courses, and confine the creeks and rivers that run between; and if we know where the gaps are that let through these streams, we are not at a loss to lay down their most considerable inflections. . . . . .

"To the northwestward of the Endless mountains is a country of vast extent, and in a manner as high as the mountains themselves. To look at the abrupt termination of it, near the sea level, as is the case on the west side of Hudson's river below Albany, it looks as a vast high mountain; for the Kaats Kills, though of more lofty stature than any other mountains in these parts of America, are but the continuation of the Plains on the top, and the cliffs of them in the front they present towards Kinderhook. These Upper Plains are of extraordinary rich level land, and extend from the Mohocks river through the country of the Confederates.* Their termination northward is at a little distance from Lake Ontario; but what it is westward is not known, for those most extensive plains of Ohio are part of them."

These several districts recognized by Evans may be summarized as the coastal plain, of nearly horizontal Cretaceous and later beds, just entering the southeastern corner of Pennsylvania; the marginal upland of contorted schists of disputed age; the South Mountain belt of ancient and much disturbed crystalline rocks, commonly called Archean; a space between these two traversed by the sandstone lowland of the Newark formation;† the great Appalachian valley of crowded Cambrian limestones and slates; the region of the even-crested, linear Paleozoic ridges, bounded by Kittatinny or Blue mountain on the southeast and by Alleghany mountain on the northwest, this being the area with which we are here most concerned; and finally the Alleghany plateau, consisting of nearly horizontal Devonian and Carboniferous beds and embracing all the western part of the state. The whole region presents the most emphatic expression not only of its structure but also of the more recent cycles of development through which it has passed. Fig. 1 represents the stronger ridges and larger streams of the greater part of the central district: it is reproduced from the expressive Topographic Map of Pennsylvania (1871) by Lesley. The Susquehanna flows down the middle, receiving the West Branch from Lock Haven

* Referring to the league of Indian tribes, so-called.

† Russell has lately recommended the revival of this term, proposed many years ago by Redfield, as a non-committal name for the "New red sandstones" of our Atlantic slope, commonly called Triassic.

FIG. 1. Part of Topographic Map of Pennsylvania, by J. P. Lesley (1871).

and Williamsport, the East Branch from Wilkes-Barre in the Wyoming basin, and the Juniata from the Broad Top region, south of Huntingdon. The Anthracite basins lie on the right, enclosed by zigzag ridges of Pocono and Pottsville sandstone; the Plateau, trenched by the West Branch of the Susquehanna is in the northwest. Medina sandstone forms most of the central ridges.

3. *The drainage of Pennsylvania.*—The greater part of the Alleghany plateau is drained westward into the Ohio, and with this we shall have little to do. The remainder of the plateau drainage reaches the Atlantic by two rivers, the Delaware and the Susquehanna, of which the latter is the more special object of our study. The North and West Branches of the Susquehanna rise in the plateau, which they traverse in deep valleys; thence they enter the district of the central ranges, where they unite and flow in broad lowlands among the even-crested ridges. The Juniata brings the drainage of the Broad Top region to the main stream just before their confluent current cuts across the marginal Blue Mountain. The rock-rimmed basins of the anthracite region are drained by small branches of the Susquehanna northward and westward, and by the Schuylkill and Lehigh to the south and east. The Delaware, which traverses the plateau between the Anthracite region and the Catskill Mountain front, together with the Lehigh, the Schuylkill, the little Swatara and the Susquehanna, cut the Blue Mountain by fine water-gaps, and cross the great limestone valley. The Lehigh then turns eastward and joins the Delaware, and the Swatara turns westward to the Susquehanna; but the Delaware, Schuylkill and Susquehanna all continue across South Mountain and the Newark belt, and into the low plateau of schists beyond. The Schuylkill unites with the Delaware near Philadelphia, just below the inner margin of the coastal plain; the Delaware and the Susquehanna continue in their deflected estuaries to the sea. All of these rivers and many of their side streams are at present sunk in small valleys of moderate depth and width, below the general surface of the lowlands, and are more or less complicated with terrace gravels.

4. *Previous studies of Appalachian drainage.*—There have been no special studies of the history of the rivers of Pennsylvania in the light of what is now known of river development. A few recent essays of rather general character as far as our rivers are concerned, may be mentioned.

Peschel examined our rivers chiefly by means of general maps with little regard to the structure and complicated history of the region. He concluded that the several transverse rivers which break through the mountains, namely, the Delaware, Susquehanna and Potomac, are guided by fractures, anterior to the origin of the rivers.* There does not seem to be sufficient evidence to support this obsolescent view, for most of the water-gaps are located independently of fractures; nor can Peschel's method of river study be trusted as leading to safe conclusions.

Tietze regards our transverse valleys as antecedent;† but this was made only as a general suggestion, for his examination of the structure and development of the region is too brief to establish this and exclude other views.†

Löwl questions the conclusion reached by Tietze and ascribes the transverse gaps to the backward or headwater erosion of external streams, a process which he has done much to bring into its present important position, and which for him replaces the persistence of antecedent streams of other authors.‡

A brief article§ that I wrote in comment on Löwl's first essay several years ago now seems to me insufficient in its method. It exaggerated the importance of antecedent streams; it took no sufficient account of the several cycles of erosion through which the region has certainly passed; and it neglected due consideration of the readjustment of initial immature stream courses during more advanced river-life. Since then, a few words in Löwl's essay have come to have more and more significance to me; he says that in mountain systems of very great age, the original arrangement of the longitudinal valleys often becomes entirely confused by means of their conquest by transverse erosion gaps. This suggestion has been so profitable to me that I have placed the original sentence at the beginning of this paper. Its thesis is the essential element of my present study.

Phillipson refers to the above-mentioned authors and gives a brief account of the arrangement of drainage areas within our Appalachians, but briefly dismisses the subject.‖ His essay contains a serviceable bibliography.

If these several earlier essays have not reached any precise

* Physische Erdkunde, 1880, ii, 442.
† Jahrbuch Geol. Reichsanstalt, xxviii, 1878, 600.
‡ Pet. Mitth., 1882, 405; Ueber Thalbildung, Prag, 1884.
§ Origin of Cross-valleys. Science, i, 1883, 325.
‖ Studien über Wasserscheiden. Leipsig, 1886, 149.

conclusion, it may perhaps be because the details of the geological structure and development of Pennsylvania have not been sufficiently examined. Indeed, unless the reader has already become familiar with the geological maps and reports of the Pennsylvania surveys and is somewhat acquainted with its geography, I shall hardly hope to make my case clear to him. The volumes that should be most carefully studied are, first, the always inspiring classic, "Coal and its Topography" (1856), by Lesley, in which the immediate relation of our topography to the underlying structure is so finely described; the Geological Map of Pennsylvania (1856), the result of the labors of the first survey of the state; and the Geological Atlas of Counties, Volume X of the second survey (1885). Besides these, the ponderous volumes of the final report of the first survey and numerous reports on separate counties by the second survey should be examined, as they contain many accounts of the topography although saying very little about its development. If, in addition to all this, the reader has seen the central district of the state and marvelled at its even-crested, straight and zigzag ridges, and walked through its narrow water-gaps into the enclosed coves that they drain, he may then still better follow the considerations here presented.

PART SECOND. *Outline of the geological history of the region.*

5. *Conditions of formation.*—The region in which the Susquehanna and the neighboring rivers are now located is built in chief part of marine sediments derived in paleozoic time from a large land area to the southeast, whose northwest coast-line probably crossed Pennsylvania somewhere in the southeastern part of the state; doubtless varying its position, however, by many miles as the sea advanced and receded in accordance with the changes in the relative altitudes of the land and water surfaces, such as have been discussed by Newberry and Claypole. The sediments thus accumulated are of enormous thickness, measuring twenty or thirty thousand feet from their crystalline foundation to the uppermost layer now remaining. The whole mass is essentially conformable in the central part of the state. Some of the formations are resistent, and these have determined the position of our ridges; others are weaker and are chosen as the sites of valleys and lowlands. The first are the Oneida and Medina sandstones, which will be here generally referred to under the latter name alone, the Pocono sandstone and the Pottsville conglomerate; to these may be added the fundamental crystalline mass on which

the whole series of bedded formations was deposited, and the basal sandstone that is generally associated with it. Wherever we now see these harder rocks, they rise above the surrounding lowland surface. On the other hand, the weaker beds are the Cambrian limestones (Trenton) and slates (Hudson River), all the Silurian except the Medina above named, the whole of the Devonian—in which however there are two hard beds of subordinate value, the Oriskany sandstone and a Chemung sandstone and conglomerate, that form low and broken ridges over the softer ground on either side of them—and the Carboniferous (Mauch Chunk) red shales and some of the weaker sandstones (Coal measures).

6. *Former extension of strata to the southeast.*—We are not much concerned with the conditions under which this great series of beds was formed ; but, as will appear later, it is important for us to recognize that the present southeastern margin of the beds is not by any means their original margin in that direction. It is probable that the whole mass of deposits, with greater or less variations of thickness, extended at least twenty miles southeast of Blue Mountain, and that many of the beds extended much farther. The reason for this conclusion is a simple one. The several resistant beds above-mentioned consist of quartz sand and pebbles that cannot be derived from the underlying beds of limestones and shales ; their only known source lay in the crystalline rocks of the paleozoic land to the southeast. South Mountain may possibly have made part of this paleozoic land ; but it seems more probable that it was land only during the earlier Archean age, and that it was submerged and buried in Cambrian time and not again brought to the light of day until it had been crushed into many local anticlines* whose crests were uncovered by Permian and later erosion. The occurrence of Cambrian limestone on either side of South Mountain, taken with its compound anticlinal structure, makes it likely that Medina time found this crystalline area entirely covered by the Cambrian beds ; Medina sands must therefore have come from farther still to the southeast. A similar argument applies to the source of the Pocono and Pottsville beds. The measure of twenty miles as the former southeastern extension of the paleozoic formations therefore seems to be a moderate one for the average of the whole series ; perhaps forty would be nearer the truth.

* Lesley, as below.

7. *Cambro-Silurian and Permian deformations.*—This great series of once horizontal beds is now wonderfully distorted; but the distortions follow a general rule of trending northeast and southwest, and of diminishing in intensity from southeast to northwest. In the Hudson Valley, it is well known that a considerable disturbance occurred between Cambrian and Silurian time, for there the Medina lies unconformably on the Hudson River shales. It seems likely, for reasons that will be briefly given later on, that the same disturbance extended into Pennsylvania and farther southwest, but that it affected only the southeastern corner of the State; and that the unconformities in evidence of it, which are preserved in the Hudson Valley, are here lost by subsequent erosion. Waste of the ancient land and its Cambro-Silurian annex still continued and furnished vast beds of sandstone and sandy shales to the remaining marine area, until at last the subsiding Paleozoic basin was filled up and the coal marshes extended broadly across it. At this time we may picture the drainage of the southeastern land area wandering rather slowly across the great Carboniferous plains to the still submerged basin far to the west; a condition of things that is not imperfectly represented, although in a somewhat more advanced stage, by the existing drainage of the mountains of the Carolinas across the more modern coastal plain to the Atlantic.

This condition was interrupted by the great Permian deformation that gave rise to the main ranges of the Appalachians in Pennsylvania, Virginia and Tennessee. The Permian name seems appropriate here, for while the deformation may have begun at an earlier date, and may have continued into Triassic time, its culmination seems to have been within Permian limits. It was characterized by a resistless force of compression, exerted in a southeast-northwest line, in obedience to which the whole series of Paleozoic beds, even twenty or more thousand feet in thickness, was crowded gradually into great and small folds, trending northeast and southwest. The subjacent Archean terrane doubtless shared more or less in the disturbance: for example, South Mountain is described by Lesley as "not one mountain, but a system of mountains separated by valleys. It is, geologically considered, a system of anticlinals with troughs between. . . . . . It appears that the South Mountain range ends eastward [in Cumberland and York Counties] in a hand with five [anticlinal] fingers."*

* Proc. Amer. Phil. Soc., xiii, 1873, 6.

It may be concluded with fair probability that the folds began to rise in the southeast, where they are crowded closest together, some of them having begun here while coal marshes were still forming farther west; and that the last folds to be begun were the fainter ones on the plateau, now seen in Negro mountain and Chestnut and Laurel ridges. In consequence of the inequalities in the force of compression or in the resistance of the yielding mass, the folds do not continue indefinitely with horizontal axes, but vary in height, rising or falling away in great variety. Several adjacent folds often follow some general control in this respect, their axes rising and falling together. It is to an unequal yielding of this kind that we owe the location of the Anthracite synclinal basins in eastern Pennsylvania, the Coal Measures being now worn away from the prolongation of the synclines, which rise in either direction.

8. *Perm-Triassic denudation.*—During and for a long time after this period of mountain growth, the destructive processes of erosion wasted the land and lowered its surface. An enormous amount of material was thus swept away and laid down in some unknown ocean bed. We shall speak of this as the Perm-Triassic period of erosion. A measure of its vast accomplishment is seen when we find that the Newark formation, which is generally correlated with Triassic or Jurassic time, lies unconformably on the eroded surface of Cambrian and Archean rocks in the southeastern part of the State, where we have concluded that the Paleozoic series once existed; where the strata must have risen in a great mountain mass as a result of the Appalachian deformations; and whence they must therefore have been denuded before the deposition of the Newark beds. Not only so; the moderate sinuosity of the southeastern or under boundary of the Newark formation indicates clearly enough that the surface on which that portion of the formation lies is one of no great relief or inequality; and such a surface can be carved out of an elevated land only after long continued denudation, by which topographic development is carried beyond the time of its greatest strength or maturity into the fainter expression of old age. This is a matter of some importance in our study of the development of the rivers of Pennsylvania; and it also constitutes a good part of the evidence already referred to as indicating that there must have been some earlier deformations of importance in the southeastern part of the State; for it is hardly conceivable that the great Paleozoic

mass could have been so deeply worn off of the Newark belt between the making of the last of the coal beds and the first of the Newark. It seems more in accordance with the facts here recounted and with the teachings of geological history in general to suppose, as we have here, that something of the present deformation of the ancient rocks underlying the Newark beds was given at an early date, such as that of the Green Mountain growth; and that a certain amount of the erosion of the folded beds was thus made possible in middle Paleozoic time; then again at some later date, as Permian, a second period of mountain growth arrived, and further folding was effected, and after this came deeper erosion; thus dividing the destructive work that was done into several parts, instead of crowding it all into the post-Carboniferous time ordinarily assigned to it. It is indeed not impossible that an important share of what we have called the Permian deformation was, as above suggested, accomplished in the southeastern part of the State while the coal beds were yet forming in the west; many grains of sand in the sandstones of the Coal Measures may have had several temporary halts in other sandstone beds between the time of their first erosion from the Archean rocks and the much later time when they found the resting place that they now occupy.*

9. *Newark deposition.*—After the great Paleozoic and Perm-Triassic erosions thus indicated, when the southeastern area of ancient mountains had been well worn down and the Permian folds of the central district had acquired a well developed drainage, there appeared an opportunity for local deposition in the slow depression of a northeast-southwest belt of the deeply wasted land, across the southeastern part of the State; and into this trough-like depression, the waste from the adjacent areas on either side was carried, building the Newark formation. This may be referred to as the Newark or Trias-Jurassic period of deposition. The volume of this formation is unknown, as its thickness and original area are still undetermined; but it is pretty surely of many thousand feet in vertical measure, and its original area may have been easily a fifth or a quarter in excess of its present area, if not larger yet. So great a local accumulation seems to indicate that while the belt of deposition was

* These considerations may have value in showing that the time in which the lateral crushing of the Appalachians was accomplished was not so brief as is stated by Reade in a recent article in the American Geologist, iii, 1889, 106.

sinking, the adjacent areas were rising, in order to furnish a continual supply of material; the occurrence of heavy conglomerates along the margins of the Newark formation confirms this supposition, and the heavy breccias near Reading indicate the occurrence of a strong topography and a strong transporting agent to the northwest of this part of the Newark belt. It will be necessary, when the development of the ancestors of our present rivers is taken up, to consider the effects of the depression that determined the locus of Newark deposition and of the adjacent elevation that maintained a supply of material.

10. *Jurassic tilting.*—Newark deposition was stopped by a gradual reversal of the conditions that introduced it. The depression of the Newark belt was after a time reversed into elevation, accompanied by a peculiar tilting, and again the waste of the region was carried away to some unknown resting place. This disturbance, which may be regarded as a revival of the Permian activity, culminated in Jurassic, or at least in post-Newark time, and resulted in the production of the singular monoclinal attitude of the formation; and as far as I can correlate it with the accompanying change in the underlying structures, it involved there an over-pushing of the closed folds of the Archean and Paleozoic rocks. This is illustrated in figs. 2 and 3,

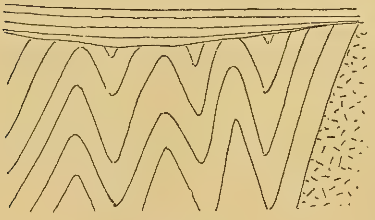


Fig. 2.

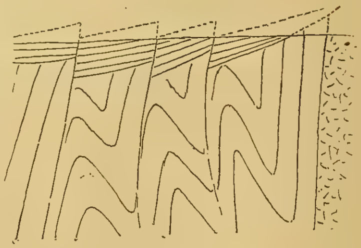


Fig. 3.

in which the original and disturbed attitudes of the Newark and the underlying formations are roughly shown, the over-pushing of the fundamental folds causing the monoclinal and probably faulted structure in the overlying beds.* If this be true, we might suspect that the unsymmetrical attitude of the Appalachian folds, noted by Rogers as a characteristic of the range, is a feature that was intensified if not originated in Jurassic and not in Permian time.

* Amer. Journ. Science, xxxii, 1886, 342; and Seventh Ann. Rept. U. S. Geol. Survey, 1888, 486.

It is not to be supposed that the Jurassic deformation was limited to the area of the Newark beds ; it may have extended some way on either side ; but it presumably faded out at no great distance, for it has not been detected in the history of the Atlantic and Mississippi regions remote from the Newark belt. In the district of the central folds of Pennsylvania, with which we are particularly concerned, this deformation was probably expressed in a further folding and over-pushing of the already partly folded beds, with rapidly decreasing effect to the north-west ; and perhaps also by slip-faults, which at the surface of the ground nearly followed the bedding planes : but this is evidently hypothetical to a high degree. The essential point for our subsequent consideration is that the Jurassic deformation was probably accompanied by a moderate elevation, for it allowed the erosion of the Newark beds and of laterally adjacent areas as well.

11. *Jura-Cretaceous denudation.*—In consequence of this elevation, a new cycle of erosion was entered upon, which I shall call the Jura-Cretaceous cycle. It allowed the accomplishment of a vast work, which ended in the production of a general lowland of denudation, a wide area of faint relief, whose elevated remnants are now to be seen in the even ridge-crests that so strongly characterize the central district, as well as in certain other even uplands, now etched by the erosion of a later cycle of destructive work. I shall not here take space for the deliberate statement of the argument leading to this end, but its elements are as follows : the extraordinarily persistent accordance among the crest-line altitudes of many Medina and Carboniferous ridges in the central district ; the generally corresponding elevation of the western plateau surface, itself a surface of erosion, but now trenched by relatively deep and narrow valleys ; the generally uniform and consistent altitude of the uplands in the crystalline highlands of northern New Jersey and in the South Mountains of Pennsylvania ; and the extension of the same general surface, descending slowly eastward, over the even crest-lines of the Newark trap ridges. Besides the evidence of less continental elevation thus deduced from the topography, it may be noted that a lower stand of the land in Cretaceous time than now is indicated by the erosion that the Cretaceous beds have suffered in consequence of the elevation that followed their deposition. The Cretaceous transgression in the western states doubtless bears on the problem

also. Finally it may be fairly urged that it is more accordant with what is known about old mountains in general to suppose that their mass has stood at different attitudes with respect to base level during their long period of denudation than to suppose that they have held one attitude through all the time since their deformation.

It is natural enough that the former maintenance of some lower altitude than the present should have expression in the form of the country, if not now extinguished by subsequent erosion. It is simply the reverse of this statement that leads us to the above-stated conclusion. We may be sure that the long maintained period of relative quiet was of great importance in allowing time for the mature adjustment of the rivers of the region, and hence due account must be taken of it in a later section. I say relative quiet, for there were certainly subordinate oscillations of greater or less value ; McGee has detected records of one of these about the beginning of Cretaceous time, but its effects are not now known to be of geographic value ; that is, they do not now manifest themselves in the form of the present surface of the land, but only in the manner of deposition and ancient erosion of certain deposits.* Another subordinate oscillation in the sense of a moderate depression seems to have extended through middle and later Cretaceous time, resulting in an inland transgression of the sea and the deposit of the Cretaceous formation unconformably on the previous land surface for a considerable distance beyond the present margin of the formation.† This is important as affecting our rivers. Although these oscillations were of considerable geological value, I do not think that for the present purposes they call for any primary division of the Jura-Cretaceous cycle ; for as the result of this long period of denudation we find but a single record in the great lowland of erosion above described, a record of prime importance in the geographic development of our region, that will often be referred to. The surface of faint relief then completed may be called the Cretaceous base-level lowland. It may be pictured as a low, undulating plain of wide extent, with a portion of its Atlantic margin submerged and covered over with a relatively thin marine deposit of sands, marls and clays.

* Amer. Jour. Science, xxxv, 1888, 367, 448.

† This statement is based on a study of the geographic evolution of northern New Jersey, in preparation for publication.

12. *Tertiary elevation and denudation.*—This broad lowland is a lowland no longer. It has been raised over the greater part of its area into a highland, with an elevation of from one to three thousand feet, sloping gently eastward and descending under the Atlantic level near the present margin of the Cretaceous formation. The elevation seems to have taken place early in Tertiary time, and will be referred to as of that date. Opportunity was then given for the revival of the previously exhausted forces of denudation, and as a consequence we now see the formerly even surface of the plain greatly roughened by the incision of deep valleys and the opening of broad lowlands on its softer rocks. Only the harder rocks retain indications of the even surface which once stretched continuously across the whole area. The best indication of the average altitude at which the mass stood through the greater part of post-Cretaceous time is to be found on the weak shales of the Newark formation in New Jersey and Pennsylvania, and on the weak Cambrian limestones of the great Kittatinny valley; for both of these areas have been actually almost baselevelled again in the Tertiary cycle. They will be referred to as the Tertiary baselevel lowlands; and the valleys corresponding to them, cut in the harder rocks, as well as the rolling lowlands between the ridges of the central district of Pennsylvania will be regarded as of the same date. Whatever variations of level occurred in this cycle of development do not seem to have left marks of importance on the inland surface, though they may have had greater significance near the coast.

13. *Later changes of level.*—Again at the close of Tertiary time, there was an elevation of moderate amount, and to this may be referred the trenches that are so distinctly cut across the Tertiary baselevel lowland by the larger rivers, as well as the lateral

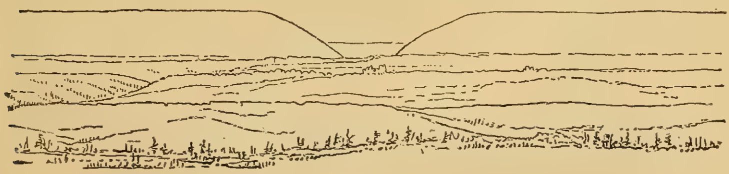


Fig. 4.

shallower channels of the smaller streams. This will be called the Quaternary cycle; and for the present no further mention of the oscillations known to have occurred in this division of time need be considered; the reader may find careful discussion of

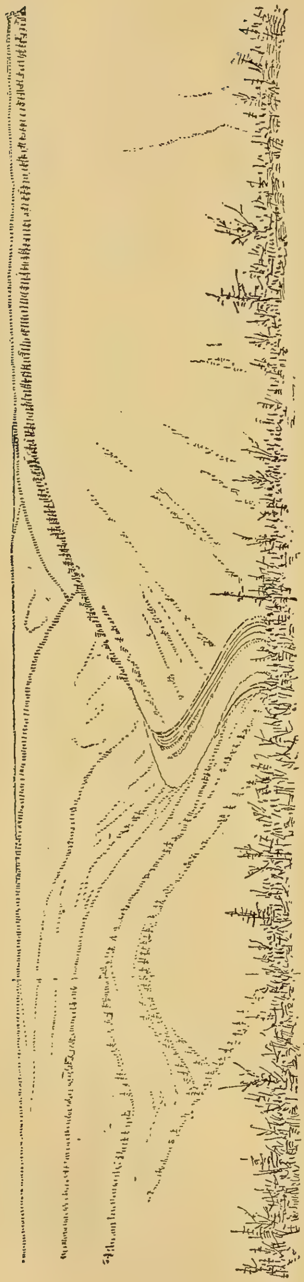


FIG. 5.

them in the paper by McGee, above referred to. It is proper that I should add that the suggestion of baselevelling both of the crest-lines and of the lowlands, that I have found so profitable in this and other work, is due largely to personal conference with Messrs. Gilbert and McGee of the Geological Survey; but it is not desired to make them in any way responsible for the statements here given.

14. *Illustrations of Pennsylvanian topography.*—A few sketches made during a recent recess-trip with several students through Pennsylvania may be introduced in this connection. The first, fig. 4, is a view from Jenny Jump mountain, on the northwestern side of the New Jersey highlands, looking northwest across the Kittatinny valley-lowland to Blue or Kittatinny mountain, where it is cut at the Delaware Water-gap. The extraordinarily level crest of the mountain preserves record of the Cretaceous baselevel lowland; since the elevation of this ancient lowland, its softer rocks have, as it were, been etched out, leaving the harder ones in relief; thus the present valley-lowland is to be explained. In consequence of the still later elevation of less amount, the Delaware has cut a trench in the present lowland, which is partly seen to the left in the sketch. Fig. 5 is a general view of the Lehigh plateau and cañon, looking south from Bald Mountain just above Penn Haven Junction. Blue mountain is the most distant crest, seen for a little space. The ridges near and above Mauch Chunk form the other outlines; all

rising to an astonishingly even altitude, in spite of their great diversity of structure. Before the existing valleys were exca-

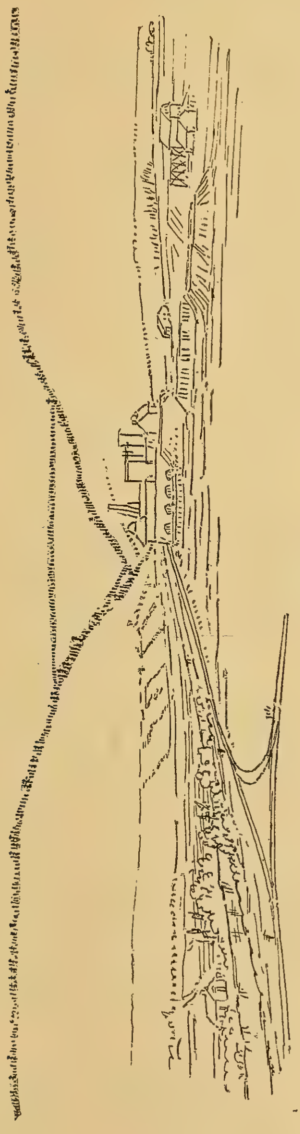


FIG. 6.

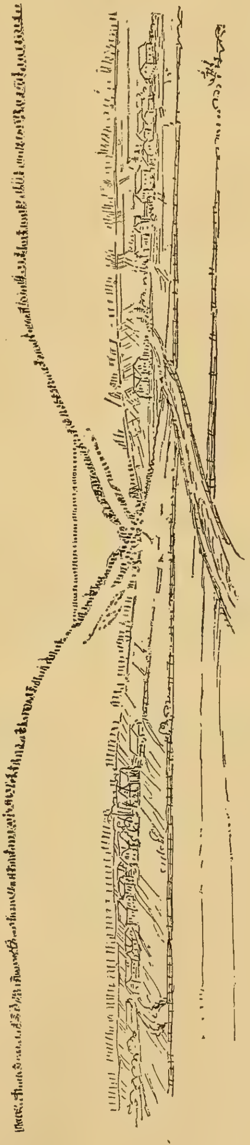


FIG. 7.

vated, the upland surface must have been an even plain—the Cretaceous baselevel lowland elevated into a plateau. The valleys cut into the plateau during the Tertiary cycle are narrow here, because the rocks are mostly hard. The steep slopes of the cañon-like valley of the Lehigh and the even crests of the ridges manifestly belong to different cycles of development. Figs. 6 and 7 are gaps cut in Black Log and Shade mountain, by a small upper branch stream of the Juniata in southeastern Huntingdon county. The stream traverses a breached anticlinal of Medina sandstone, of which these mountains are the lateral members. A long narrow valley is opened on the axial Trenton limestone between the two. The gaps are not opposite to each other, and therefore in looking through either gap from the outer country the even crest of the further ridge is seen beyond the axial valley. The gap in Black Log mountain, fig. 6, is located on a small fracture, but in this respect it is unlike most of its fellows.* The striking similarity of the two views illustrates the uniformity that so strongly characterizes the Medina ridges of the central district. Fig. 8 is in good part an ideal view, based on sketches on the

FIG. 8.

upper Susquehanna, and designed to present a typical illustration of the more significant features of the region. It shows the even crest-lines of a high Medina or Pocono ridge in the background, retaining the form given to it in the Cretaceous cycle; the even lowlands in the foreground, opened on the weaker Siluro-Devonian rocks in the Tertiary cycle; and the uneven ridges in the middle distance marking the Oriskany and Chemung beds of intermediate hardness that have lost the Cretaceous level and yet have not been reduced to the Tertiary lowland. The Susquehanna flows distinctly below the lowland plain, and the small side streams run in narrow trenches of late Tertiary and Quaternary date.

If this interpretation is accepted, and the Permian mountains are seen to have been once greatly reduced and at a later time worn out, while the ridges of to-day are merely the relief left by

* Second Geol. Surv. Pa., Report T_3, 19.

the etching of Tertiary valleys in a Cretaceous baselevelled lowland, then we may well conclude with Powell that "mountains cannot remain long as mountains; they are ephemeral topographic forms."*

PART THIRD. *General conception of the history of a river.*

15. *The complete cycle of river life: youth, adolescence, maturity and old age.*—The general outline of an ideal river's history may be now considered, preparatory to examining the special history of the rivers of Pennsylvania, as controlled by the geological events just narrated.

Rivers are so long lived and survive with more or less modification so many changes in the attitude and even in the structure of the land, that the best way of entering on their discussion seems to be to examine the development of an ideal river of simple history, and from the general features thus discovered, it may then be possible to unravel the complex sequence of events that leads to the present condition of actual rivers of complicated history.

A river that is established on a new land may be called an original river. It must at first be of the kind known as a consequent river, for it has no ancestor from which to be derived. Examples of simple original rivers may be seen in young plains, of which southern New Jersey furnishes a fair illustration. Examples of essentially original rivers may be seen also in regions of recent and rapid displacement, such as the Jura or the broken country of southern Idaho, where the directly consequent character of the drainage leads us to conclude that, if any rivers occupied these regions before their recent deformation, they were so completely extinguished by the newly made slopes that we see nothing of them now.

Once established, an original river advances through its long life, manifesting certain peculiarities of youth, maturity and old age, by which its successive stages of growth may be recognized without much difficulty. For the sake of simplicity, let us suppose the land mass, on which an original river has begun its work, stands perfectly still after its first elevation or deformation, and so remains until the river has completed its task of carrying away all the mass of rocks that rise above its baselevel. This lapse of time will be called a cycle in the life of a river. A complete

* Geol. Uinta Mountains, 1876, 196.

cycle is a long measure of time in regions of great elevation or of hard rocks; but whether or not any river ever passed through a single cycle of life without interruption we need not now inquire. Our purpose is only to learn what changes it would experience if it did thus develop steadily from infancy to old age without disturbance.

In its infancy, the river drains its basin imperfectly; for it is then embarrassed by the original inequalities of the surface, and lakes collect in all the depressions. At such time, the ratio of evaporation to rainfall is relatively large, and the ratio of transported land waste to rainfall is small. The channels followed by the streams that compose the river as a whole are narrow and shallow, and their number is small compared to that which will be developed at a later stage. The divides by which the side-streams are separated are poorly marked, and in level countries are surfaces of considerable area and not lines at all. It is only in the later maturity of a system that the divides are reduced to lines by the consumption of the softer rocks on either side. The difference between constructional forms and those forms that are due to the action of denuding forces is in a general way so easily recognized, that immaturity and maturity of a drainage area can be readily discriminated. In the truly infantile drainage system of the Red River of the North, the inter-stream areas are so absolutely flat that water collects on them in wet weather, not having either original structural slope or subsequently developed denuded slope to lead it to the streams. On the almost equally young lava blocks of southern Oregon, the well-marked slopes are as yet hardly channeled by the flow of rain down them, and the depressions among the tilted blocks are still undrained, unfilled basins.

As the river becomes adolescent, its channels are deepened and all the larger ones descend close to baselevel. If local contrasts of hardness allow a quick deepening of the down-stream part of the channel, while the part next up-stream resists erosion, a cascade or waterfall results; but like the lakes of earlier youth, it is evanescent, and endures but a small part of the whole cycle of growth; but the falls on the small headwater streams of a large river may last into its maturity, just as there are young twigs on the branches of a large tree. With the deepening of the channels, there comes an increase in the number of gulleys on the slopes of the channel; the gulleys grow into ravines and these into side valleys, joining their master streams at right angles (La Noë and Margerie). With their continued development, the maturity of the system is reached; it is marked by an almost complete acquisition of every part of the original constructional surface by erosion under the guidance of the streams, so that every drop of rain that falls finds a way prepared to lead it to a stream and then to the ocean, its goal. The lakes of initial imperfection have long since disappeared; the waterfalls of adolescence have been worn back, unless on the still young headwaters. With the increase of the number of side-streams, ramifying into all parts of the drainage basin, there is a proportionate increase in the surface of the valley slopes, and with this comes an increase in the rate of waste under atmospheric forces; hence it is at maturity that the river receives and carries the greatest load; indeed, the increase may be carried so far that the lower trunk-stream, of gentle slope in its early maturity, is unable to carry the load brought to it by the upper branches, and therefore resorts to the temporary expedient of laying it aside in a flood-plain. The level of the flood-plain is sometimes built up faster than the small side-streams of the lower course can fill their valleys, and hence they are converted for a little distance above their mouths into shallow lakes. The growth of the flood-plain also results in carrying the point of junction of tributaries farther and farther down stream, and at last in turning lateral streams aside from the main stream, sometimes forcing them to follow independent courses to the sea (Lombardini). But although thus separated from the main trunk, it would be no more rational to regard such streams as independent rivers than it would be to regard the branch of an old tree, now fallen to the ground in the decay of advancing age, as an independent plant; both are detached portions of a single individual, from which they have been separated in the normal processes of growth and decay.

In the later and quieter old age of a river system, the waste of the land is yielded slower by reason of the diminishing slopes of the valley sides; then the headwater streams deliver less detritus to the main channel, which, thus relieved, turns to its postponed task of carrying its former excess of load to the sea, and cuts terraces in its flood-plain, preparatory to sweeping it away. It does not always find the buried channel again, and perhaps settling down on a low spur a little to one side of its old line, produces a rapid or a low fall on the lower slope of such an obstruction (Penck). Such courses may be called locally superimposed.

It is only during maturity and for a time before and afterwards that the three divisions of a river, commonly recognized, appear most distinctly; the torrent portion being the still young headwater branches, growing by gnawing backwards at their sources; the valley portion proper, where longer time of work has enabled the valley to obtain a greater depth and width; and the lower flood-plain portion, where the temporary deposition of the excess of load is made until the activity of middle life is past.

Maturity seems to be a proper term to apply to this long enduring stage; for as in organic forms, where the term first came into use, it here also signifies the highest development of all functions between a youth of endeavor towards better work and an old age of relinquishment of fullest powers. It is the mature river in which the rainfall is best lead away to the sea, and which carries with it the greatest load of land waste; it is at maturity that the regular descent and steady flow of the river is best developed, being the least delayed in lakes and least overhurried in impetuous falls.

Maturity past, and the power of the river is on the decay. The relief of the land diminishes, for the streams no longer deepen their valleys although the hill tops are degraded; and with the general loss of elevation, there is a failure of rainfall to a certain extent; for it is well known that up to certain considerable altitudes rainfall increases with height. A hyetographic and a hypsometric map of a country for this reason show a marked correspondence. The slopes of the headwaters decrease and the valley sides widen so far that the land waste descends from them slower than before. Later, what with failure of rainfall and decrease of slope, there is perhaps a return to the early imperfection of drainage, and the number of side streams diminishes as branches fall from a dying tree. The flood-plains of maturity are carried down to the sea, and at last the river settles down to an old age of well-earned rest with gentle flow and light load, little work remaining to be done. The great task that the river entered upon is completed.

16. *Mutual adjustment of river courses.*—In certain structures, chiefly those of mountainous disorder on which the streams are at first high above baselevel, there is a process of adjustment extremely characteristic of quiet river development, by which the down-hill courses that were chosen in early life, and as we may say unadvisedly and with the heedlessness and little foresight of

youth, are given up for others better fitted for the work of the mature river system. A change of this kind happens when the young stream taking the lowest line for its guide happens to flow on a hard bed at a considerable height above baselevel, while its branches on one side or the other have opened channels on softer beds: a part of the main channel may then be deserted by the withdrawal of its upper waters to a lower course by way of a side stream. The change to better adjustment also happens when the initial course of the main stream is much longer than a course that may be offered to its upper portion by the backward gnawing of an adjacent stream (Löwl, Penck). Sometimes the lateral cutting or planation that characterizes the main trunk of a mature river gives it possession of an adjacent smaller stream whose bed is at a higher level (Gilbert). A general account of these processes may be found in Phillippson's serviceable "Studien über Wasserscheiden" (Leipzig, 1886). This whole matter is of much importance and deserves deliberate examination. It should be remembered that changes in river courses of the kind now referred to are unconnected with any external disturbance of the river basin, and are purely normal spontaneous acts during advancing development. Two examples, pertinent to our special study, will be considered.

Let AB, fig. 9, be a stream whose initial consequent course led it down the gently-sloping axial trough of a syncline. The constructional surface of the syncline is shown by contours. Let the succession of beds to be discovered by erosion be indicated in a section, laid in proper position on the several diagrams, but revolved into the horizontal plane, the harder beds being dotted and the baselevel standing at 00. Small side streams will soon be developed on the slopes of the syncline, in positions determined by cross-fractures or more often by what we call accident; the action of streams in similar synclines on the outside of the enclosing anticlines will be omitted for the sake of simplicity. In time, the side streams will cut through the harder upper bed M and enter the softer bed N, on which longitudinal channels, indicated by hachures, will be extended along the strike, fig. 10 (La Noë and Margerie). Let these be called "subsequent" streams. Consider two side streams of this kind, C and D, heading against each other at E, one joining the main stream lower down the axis of the syncline than the other. The headwaters of C will rob the headwaters of D, because the deepening of the channel of D is retarded by its having to join the main stream at a point where the hard bed in the axis of the fold holds the main channel

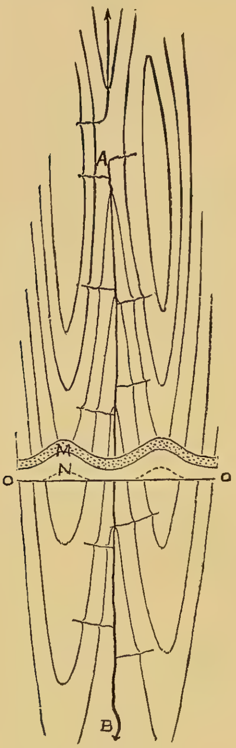


FIG. 9.

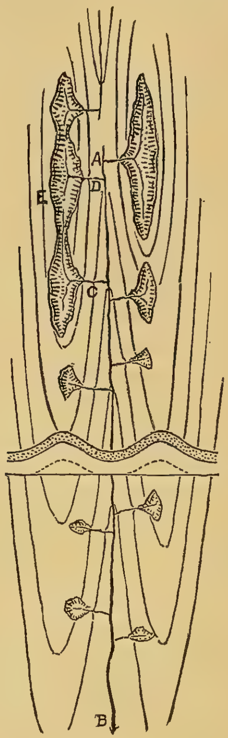


FIG. 10.

well above baselevel. The notch cut by D will then be changed from a water-gap to a wind-gap and the upper portion of D will find exit through the notch cut by C, as in fig. 11. As other subsequent headwaters make capture of C, the greater depth to which the lateral valley is cut on the soft rock causes a slow migration of the divides in the abandoned gaps towards the main stream, and before long the upper part of the main stream itself will be led out of the synclinal axis to follow the monoclinal valley at one side for a distance, fig. 12, until the axis can be rejoined through the gap where the axial portion of the controlling hard bed is near or at baselevel. The upper part of the synclinal trough will then be attacked by undercutting on the slope of the quickly deepened channels of the lateral streams, and the hard bed will be worn away in the higher part of the axis before it is consumed in the lower part. The location of the successful lateral stream on one or the other side of the syncline may be

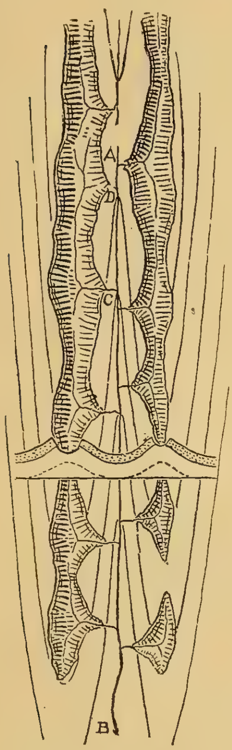


Fig. 11.

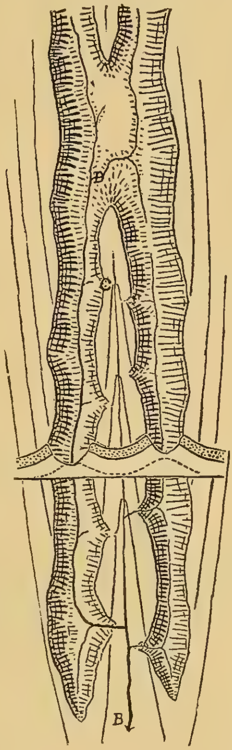


Fig. 12.

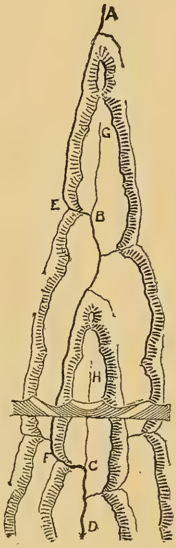


Fig. 13.

determined by the dip of the beds, gaps being cut quicker on steep than on gentle dips. If another hard bed is encountered below the soft one, the process will be repeated; and the mature arrangement of the streams will be as in fig. 13 (on a smaller scale than the preceding), running obliquely off the axis of the fold where a hard bed of the syncline rises above baselevel, and returning to the axis where the hard bed is below or at baselevel; a monoclinal stream wandering gradually from the axis along the strike of the soft bed, AE, by which the side-valley is located and returning abruptly to the axis by a cataclinal* stream in a

* See the terminology suggested by Powell. Expl. Col. R. of the West, 1875, 160. This terminology is applicable only to the most detailed study of our rivers, by reason of their crossing so many folds, and changing so often from longitudinal to transverse courses.

transverse gap, EB, in the next higher hard bed, and there rejoining the diminished representative or survivor of the original axial or synclinal stream, GB.

17. *Terminology of rivers changed by adjustment.*—A special terminology is needed for easy reference to the several parts of the streams concerned in such an adjustment. Let AB and CD, fig. 14, be streams of unequal size cutting gaps, H and G, in a ridge that lies transverse to their course. CD being larger than AB will deepen its gap faster. Of two subsequent streams, JE and JF, growing on the up-stream side of the ridge, JE will have the steeper slope, because it joins the deeper master-stream. The divide, J, will therefore be driven towards AB, and if all the conditions concerned conspire favorably, JE will at last tap AB at F, and lead the upper part, AF, out by the line FEGD, fig. 15,

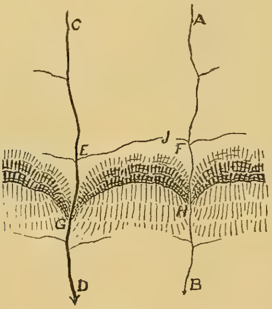


Fig. 14.

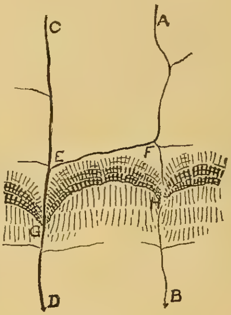


Fig. 15.

through the deeper gap, G. We may then say that JE becomes the *divertor* of AF, which is *diverted;* and when the process is completed, by the transfer of the divide from J, on the soft rocks, to a stable location, H, on the hard rocks, there will be a short *inverted* stream, HF; while HB is the remaining *beheaded* portion of the original stream, AB, and the water-gap of AB becomes a wind-gap, H. It is very desirable that geographic exploration should discover examples of the process of adjustment in its several stages. The preparatory stage is easily recognized by the difference in the size of the two main streams, the difference in the depth of their gaps, and the unsymmetrical position of the divide, J. The very brief stage of transition gives us the rare examples of bifurcating streams. For a short time after capture of the diverted stream by the divertor, the new divide will lie between F and H, in an unstable position, the duration of this time depending on the energy of the process of capture.

The consequences resulting from readjustments of this kind by which their recent occurrence can be detected are: a relatively sudden increase of volume of the divertor and hence a rapid deepening of the course of the diverting stream, FE, and of the diverted, AF, near the point of capture; small side-streams of these two being unable to keep pace with this change will join their masters in local rapids, which work up stream gradually and fade away (Löwl, Penck, McGee). The expanded portion, ED, of the larger stream, CD, already of faint slope, may be locally overcome for a time with the increase of detritus that will be thus delivered to it at the entrance, E, of the divertor; while the beheaded stream, HB, will find itself embarrassed to live up to the habits of its large valley [Heim]. Geographic exploration

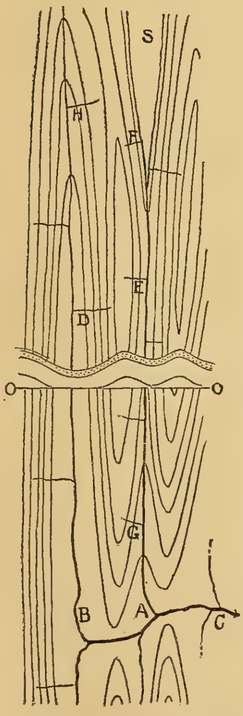


Fig. 16.

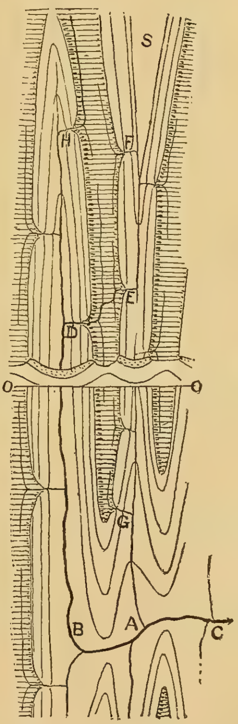


Fig. 17.

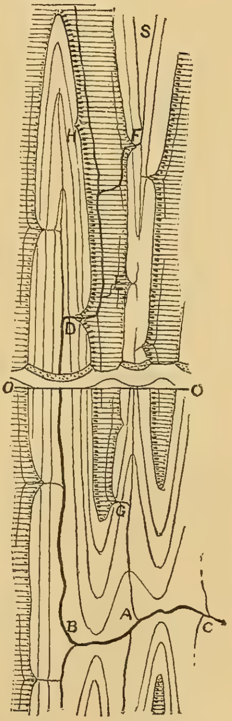


Fig. 18.

with these matters in mind offers opportunity for the most attractive discoveries.

18. *Examples of adjustment.*—Another case is roughly figured

in the next three diagrams, figs. 16, 17, 18. Two adjacent synclinal streams, EA and HB, join a transverse master stream, C, but the synclines are of different forms ; the surface axis of one, EA, stands at some altitude above baselevel until it nearly reaches the place of the transverse stream ; while the axis of the other, HB, descends near baselevel at a considerable distance from the transverse stream. As lateral valleys, E and D, are opened on the anticline between the synclines by a process similar to that already described, the divide separating them will shift towards the stream of fainter slope, that is, towards the syncline, EA, whose axis holds its hard beds above baselevel ; and in time the upper part of the main stream will be withdrawn from this syncline to follow an easier course by crossing to the other, as in fig. 17. If the elevation of the synclinal axis, AES, take the shape of a long flat arch, descending at the further end into a synclinal lake basin, S, whose outlet is along the arching axis, SA, then the mature arrangement of stream courses will lead the lake outlet away from the axis by some gap in the nearer ascending part of the arch where the controlling hard bed falls near to baselevel, as at F, fig. 18,* and will take it by some subsequent course, FD, across the lowland that is opened on the soft beds between the synclines, and carry it into the lower syncline, HB, at D where the hard beds descend below baselevel.

The variety of adjustments following the general principle here indicated is infinite. Changes of greater or less value are thus introduced in the initial drainage areas, until, after attaining an attitude of equilibrium, further change is arrested, or if occurring, is relatively insignificant. It should be noticed that the new stream courses thus chosen are not named by any of the terms now current to express the relation of stream and land history ; they are neither consequent, antecedent nor superimposed. The stream is truly still an original stream, although no longer young ; but its channel is not in all parts strictly consequent on the initial constructional form of the land that it drains. Streams thus re-arranged may therefore be named original streams of mature adjustment.

It should be clearly recognized that the process of adjustment is a very slow one, unless measured in the extremely long units

* This figure would be improved if a greater amount of wasting around the margin of the hard bed were indicated in comparison with the preceding figure.

of a river's life. It progresses no faster than the weathering away of the slopes of a divide, and here as a rule weathering is deliberate to say the least, unless accelerated by a fortunate combination of favoring conditions. Among these conditions, great altitude of the mass exposed to erosion stands first, and deep channeling of streams below the surface—that is, the adolescent stage of drainage development—stands second. The opportunity for the lateral migration of a divide will depend on the inequality of the slopes on its two sides, and here the most important factors are length of the two opposite stream courses from the water parting to the common baselevel of the two, and inequality of structure by which one stream may have an easy course and the other a hard one. It is manifest that all these conditions for active shifting of divides are best united in young and high mountain ranges, and hence it is that river adjustments have been found and studied more in the Alps than elsewhere.

19. *Revival of rivers by elevation and drowning by depression.*—I make no contention that any river in the world ever passed through a simple uninterrupted cycle of the orderly kind here described. But by examining many rivers, some young and some old, I do not doubt that this portrayal of the ideal would be found to be fairly correct if opportunity were offered for its development. The intention of the sketch is simply to prepare the way for the better understanding of our actual rivers of more complicated history.

At the close or at any time during the passage of an initial cycle such as the one just considered, the drainage area of a river system may be bodily elevated. The river is then turned back to a new youth and enters a new cycle of development. This is an extremely common occurrence with rivers, whose life is so long that they commonly outlive the duration of a quiescent stage in the history of the land. Such rivers may be called revived. Examples may be given in which streams are now in their second or third period of revival, the elevations that separate their cycles following so soon that but little work was accomplished in the quiescent intervals.

The antithesis of this is the effect of depression, by which the lower course may be drowned, flooded or fjorded. This change is, if slow, favorable to the development of flood-plains in the lower course; but it is not essential to their production. If the change is more rapid, open estuaries are formed, to be transformed to delta-lowlands later on.

20. *Opportunity for new adjustments with revival.*—One of the most common effects of the revival of a river by general elevation is a new adjustment of its course to a greater or less extent, as a result of the new relation of baselevel to the hard and soft beds on which the streams had adjusted themselves in the previous cycle. Synclinal mountains are most easily explained as results of drainage changes of this kind [Science, Dec. 21st, 1888]. Streams thus rearranged may be said to be adjusted through elevation or revival. It is to be hoped that, as our study advances, single names of brief and appropriate form may replace these paraphrases ; but at present it seems advisable to keep the desired idea before the mind by a descriptive phrase, even at the sacrifice of brevity. A significant example may be described.

Let it be supposed that an originally consequent river system has lived into advanced maturity on a surface whose structure is, like that of Pennsylvania, composed of closely adjacent anticlinal and synclinal folds with rising and falling axes, and that a series of particularly resistant beds composes the upper members of the folded mass. The master stream, A, fig. 19, at maturity still resides where the original folds were lowest, but the side streams have departed more less from the axes of the synclinals that they first followed, in accordance with the principles of adjustment presented above. The relief of the surface is moderate, except around the synclinal troughs, where the rising margins of the hard beds still appear as ridges of more or less prominence. The minute hachures in figure 19 are drawn on the outcrop side of these ridges. Now suppose a general elevation of the region, lifting the synclinal troughs of the hard beds up to baselevel or even somewhat above it. The deepening of the revived master-stream will be greatly retarded by reason of its having to cross so many outcrops of the hard beds, and thus excellent opportunity will be given for readjustment by the growth of some diverting stream, B, whose beginning on adjacent softer rocks was already made in the previous cycle. This will capture the main river at some up-stream point, and draw it nearly all away from its hard path across the synclinal troughs to an easier path across the lowlands that had been opened on the underlying softer beds, leaving only a small beheaded remnant in the lower course. The final re-arrangement may be indicated in fig. 20. It should be noted that every capture of branches of the initial main stream made by the diverting stream adds to its ability for further encroachments, for with increase of volume the channel is deepened and a

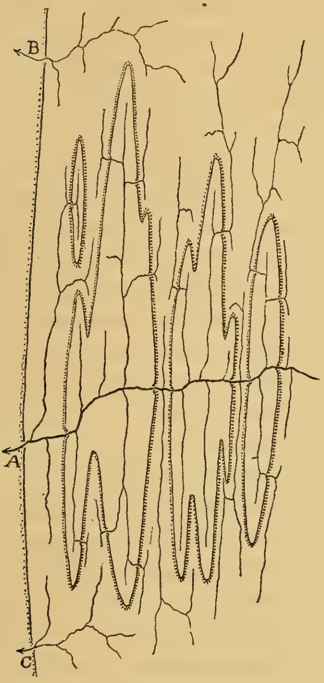


Fig. 19.

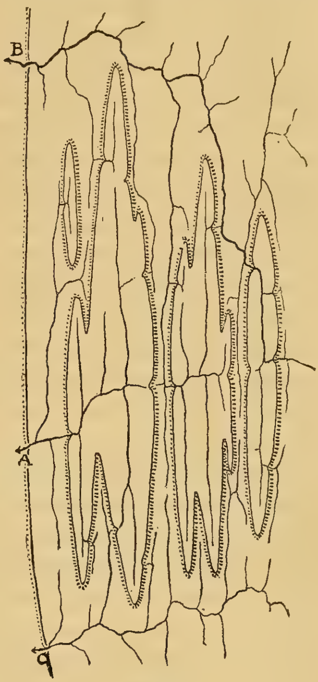


Fig. 20.

flatter slope is assumed, and the whole process of pushing away the divides is thereby accelerated. In general it may be said that the larger the stream and the less its elevation above baselevel, the less likely is it to be diverted, for with large volume and small elevation it will early cut down its channel so close to baselevel that no other stream can offer it a better course to the sea ; it may also be said that, as a rule, of two equal streams, the headwaters of the one having a longer or a harder course will be diverted by a branch of the stream on the shorter or easier course. Every case must therefore be examined for itself before the kind of re-arrangement that may be expected or that may have already taken place can be discovered.

21. *Antecedent and superimposed rivers.*—It not infrequently happens that the surface, on which a drainage system is more or less fully developed, suffers deformation by tilting, folding or faulting. Then, in accordance with the rate of disturbance, and

dependent on the size and slope of the streams and the resistance of the rocks, the streams will be more or less re-arranged, some of the larger ones persisting in their courses and cutting their channels down almost as fast as the mass below them is raised and offered to their action. It is manifest that streams of large volume and considerable slope are the ones most likely to persevere in this way, while small streams and large ones of moderate slope may be turned from their former courses to new courses consequent on the new constructional form of the land. Hence, after a disturbance, we may expect to find the smaller streams of the former cycle pretty completely destroyed, while some of the larger ones may still persist; these would then be called antecedent streams in accordance with the nomenclature introduced by Powell.* A fuller acquaintance with the development of our rivers will probably give us examples of river systems of all degrees of extinction or persistence at times of disturbance.

Since Powell introduced the idea of antecedent valleys and Tietze, Medlicott and others showed the validity of the explanation in other regions than the one for which it was first proposed, it has found much acceptance. Lōwl's objection to it does not seem to me to be nearly so well founded as his suggestion of an additional method of river development by means of backward headwater erosion and subsequent capture of other streams, as already described. And yet I cannot help thinking that the explanation of transverse valleys as antecedent courses savors of the Gordian method of explaining a difficult matter. The case of the Green river, to which Powell first gave this explanation, seems well supported; the examples given by Medlicott in the Himalayas are as good: but still it does not seem advisable to explain all transverse streams in this way, merely because they are transverse. Perhaps one reason why the explanation has become so popular is that it furnishes an escape from the old catastrophic idea that fractures control the location of valleys, and is at the same time fully accordant with the ideas of the uniformitarian school that have become current in this half of our century. But when it is remembered that most of the streams of a region are extinguished at the time of mountain growth, that only a few of the larger ones can survive, and that there are other ways in which transverse streams may originate,† it is evi-

* Exploration of the Colorada River of the West, 1875, 153, 163–166.
† Hilber, Pet. Mitth., xxxv, 1889, 13.

dent that the possibility of any given transverse stream being antecedent must be regarded only as a suggestion, until some independent evidence is introduced in its favor. This may be difficult to find, but it certainly must be searched for; if not then forthcoming, the best conclusion may be to leave the case open until the evidence appears. Certainly, if we find a river course that is accordant in its location with the complicated results of other methods of origin, then the burden of proof may be said to lie with those who would maintain that an antecedent origin would locate the river in so specialized a manner. Even if a river persist for a time in an antecedent course, this may not prevent its being afterwards affected by the various adjustments and revivals that have been explained above: rivers so distinctly antecedent as the Green and the Sutlej may hereafter be more or less affected by processes of adjustment, which they are not yet old enough to experience. Hence in mountains as old as the Appalachians the courses of the present rivers need not coincide with the location of the pre-Permian rivers, even if the latter persisted in their courses through the growth of the Permian folding; subsequent elevations and adjustments to hard beds, at first buried and unseen, may have greatly displaced them, in accordance with Löwl's principle.

When the deeper channelling of a stream discovers an unconformable subjacent terrane, the streams persist at least for a time in the courses that were determined in the overlying mass; they are then called superimposed (Powell), inherited (Shaler), or epigenetic (Richthofen). Such streams are particularly liable to readjustment by transfer of channels from courses that lead them over hard beds to others on which the hard beds are avoided; for the first choice of channels, when the unconformable cover was still present, was made without any knowledge of the buried rock structure or of the difficulties in which the streams would be involved when they encountered it. The examples of falls produced when streams terrace their flood-plains and run on buried spurs has already been referred to as superimposed; and the rivers of Minnesota now disclosing half-buried ledges here and there may be instanced as illustrating the transition stage between simple consequent courses, determined by the form of the drift sheet on which their flow began, and the fully inconsequent courses that will be developed there in the future.

22. *Simple, compound, composite and complex rivers.*—We

have thus far considered an ideal river. It now seems advisable to introduce a few terms with which to indicate concisely certain well marked peculiarities in the history of actual rivers.

An original river has already been defined as one which first takes possession of a land area, or which replaces a completely extinguished river on a surface of rapid deformation.

A river may be simple, if its drainage area is of practically one kind of structure and of one age; like the rivers of southern New Jersey. Such rivers are generally small. It may be composite, when drainage areas of different structure are included in the basin of a single stream. This is the usual case.

A compound river is one which is of different ages in its different parts; as certain rivers of North Carolina, which have old headwaters rising in the mountains, and young lower courses traversing the coastal plain.

A river is complex when it has entered a second or later cycle of development; the headwaters of a compound river are therefore complex, while the lower course may be simple, in its first cycle. The degree of complexity measures the number of cycles that the river has entered.

When the study of rivers is thus attempted, its necessary complications may at first seem so great as to render it of no value; but in answer to this I believe that it may be fairly urged that, although complicated, the results are true to nature, and if so, we can have no ground of complaint against them. Moreover, while it is desirable to reduce the study of the development of rivers to its simplest form, in order to make it available for instruction and investigation, it must be remembered that this cannot be done by neglecting to investigate the whole truth in the hope of avoiding too great complexity, but that simplicity can be reached safely only through fullness of knowledge, if at all.

It is with these points in mind that I have attempted to decipher the history of the rivers of Pennsylvania. We find in the Susquehanna, which drains a great area in the central part of the state, an example of a river which is at once composite, compound and highly complex. It drains districts of divers structure; it traverses districts of different ages; and it is at present in its fourth or fifth degree of complexity, its fourth or fifth cycle of development at least. In unravelling its history and searching out the earlier courses of streams which may have long since been abandoned in the processes of mature adjustment, it will be seen that the size of the present streams is not always a measure of their previous importance, and to this we may ascribe the difficulty that attends the attempt to decipher a river's history from general maps of its stream lines. Nothing but a detailed examination of geological structure and history suffices to detect facts and conditions that are essential to the understanding of the result.

If the postulates that I shall use seem unsound and the arguments seem overdrawn, error may at least be avoided by not holding fast to the conclusions that are presented, for they are presented only tentatively. I do not feel by any means absolutely persuaded of the correctness of the results, but at the same time deem them worth giving out for discussion. The whole investigation was undertaken as an experiment to see where it might lead, and with the hope that it might lead at least to a serious study of our river problems.

PART FOURTH. *The development of the rivers of Pennsylvania.*

23. *Means of distinguishing between antecedent and adjusted consequent rivers.*—The outline of the geological history of Pennsylvania given above affords means of dividing the long progress of the development of our rivers into the several cycles which make up their complete life. We must go far back into the past and imagine ancient streams flowing down from the Archean land towards the paleozoic sea; gaining length by addition to their lower portions as the land grew with the building on of successive mountain ranges; for example, if there were a Cambro-Silurian deformation, a continuation of the Green Mountains into Pennsylvania, we suppose that the pre-existent streams must in some manner have found their way westward to the new coast-line; and from the date of this mountain growth, it is apparent that any streams then born must have advanced far in their history before the greater Appalachian disturbance began. At the beginning of the latter, as of the former, there must have been streams running from the land into the sea, and at times of temporary elevation of the broad sand-flats of the coal measures, such streams must have had considerable additions to their lower length; rising in long-growing Archean highlands or mountains, snow-capped and drained by glaciers for all we can say to the contrary, descending across the Green Mountain belt, by that time worn to moderate relief in the far advanced stage of its

topographic development, and finally flowing across the coal-measure lowlands of recent appearance. It was across the lower courses of such rivers that the Appalachian folds were formed, and the first step in our problem consists in deciding if possible whether the streams held their courses after the antecedent fashion, or whether they were thrown into new courses by the growing folds, so that a new drainage systen would be formed. Possibly both conditions prevailed ; the larger streams holding their courses little disturbed, and the smaller ones disappearing, to be replaced by others as the slopes of the growing surface should demand. It is not easy to make choice in this matter. To decide that the larger streams persisted and are still to be seen in the greater rivers of to-day, only reversed in direction of flow, is certainly a simple method of treating the problem, but unless some independent reasons are found for this choice, it savors of assumption. Moreover, it is difficult to believe that any streams, even if antecedent and more or less persistent for a time during the mountain growth, could preserve till now their pre-Appalachain courses through all the varying conditions presented by the alternations of hard and soft rocks through which they have had to cut, and at all the different altitudes above baselevel in which they have stood. A better means of deciding the question will be to admit provisionally the occurrence of a completely original system of consequent drainage, located in perfect accord with the slopes of the growing mountains; to study out the changes of stream-courses that would result from later disturbances and from the mutual adjustments of the several members of such a system in the different cycles of its history ; and finally to compare the courses thus deduced with those now seen. If there be no accord, either the method is wrong or the streams are not consequent but of some other origin, such as antecedent ; if the accord between deduction and fact be well marked, varying only where no definite location can be given to the deduced streams, but agreeing where they can be located more precisely, then it seems to me that the best conclusion is distinctly in favor of the correctness of the deductions. For it is not likely, even if it be possible, that antecedent streams should have accidentally taken, before the mountains were formed, just such locations as would have resulted from the subsequent growth of the mountains and from the complex changes in the initial river courses due to later adjustments. I shall therefore follow the deductive method thus indicated and attempt to trace out the history of a completely original, consequent system of drainage accordant with the growth of the central mountain district.

In doing this, it is first necessary to restore the constructional topography of the region; that is, the form that the surface would have had if no erosion had accompanied its deformation. This involves certain postulates which must be clearly conceived if any measure of confidence is to be gained in the results based upon them.

24. *Postulates of the argument.*—In the first place, I assume an essential constancy in the thickness of the paleozoic sediments over the entire area in question. This is warranted here because the known variations of thickness are relatively of a second order, and will not affect the distribution of high and low ground as produced by the intense Permian folding. The reasons for maintaining that the whole series had a considerable extension southeast of the present margin of the Medina sandstone have already been presented.

In the second place, I shall assume that the dips and folds of the beds now exposed at the surface of the ground may be projected upwards into the air in order to restore the form of the eroded beds. This is certainly inadmissible in detail, for it cannot be assumed that the folded slates and limestones of the Nittany valley, for instance, give any close indication of the form that the coal measures would have taken, had they extended over this district, unworn. But in a general way, the Nittany massif was a complex arch in the coal measures as well as in the Cambrian beds; for our purpose and in view of the moderate relief of the existing topography, it suffices to say that wherever the lower rocks are now revealed in anticlinal structure, there was a great upfolding and elevation of the original surface; and wherever the higher rocks are still preserved, there was a relatively small elevation.

In the third place, I assume that by reconstructing from the completed folds the form which the country would have had if unworn, we gain a sufficiently definite picture of the form through which it actually passed at the time of initial and progressive folding. The difference between the form of the folds completely restored and the form that the surface actually reached is rather one of degree than of kind; the two must correspond in the general distribution of high and low ground and this is the chief consideration in our problem. When we remember how accurately water finds its level, it will be clearer that what is needed in the discussion is the location of the regions that were relatively raised and lowered, as we shall then have marked out the general course of the consequent water ways and the trend of the intervening constructional ridges.

Accepting these postulates, it may be said in brief that the outlines of the formations as at present exposed are in effect so many contour lines of the old constructional surface, on which the Permian rivers took their consequent courses. Where the Trenton limestone is now seen, the greatest amount of overlying strata must have been removed ; hence the outline of the Trenton formation is our highest contour line. Where the Helderberg limestone appears, there has been a less amount of material removed ; hence the Helderberg outcrop is a contour of less elevation. Where the coal beds still are preserved, there has been least wasting, and these beds therefore mark the lowest contour of the early surface. It is manifest that this method assumes that the present outcrops are on a level surface ; this is not true, for the ridges through the State rise a thousand feet more or less over the intervening valley lowlands, and yet the existing relief does not count for much in discussing the enormous relief of the Permian surface that must have been measured in tens of thousands of feet at the time of its greatest strength.

25. *Constructional Permian topography and consequent drainage.*—A rough restoration of the early constructional topography is given in fig. 21 for the central part of the State, the closest shading being the area of the Trenton limestone, indicating the highest ground, or better, the places of greatest elevation, while the Carboniferous area is unshaded, indicating the early lowlands. The prevalence of northeast and southwest trends was then even more pronounced than now. Several of the stronger elements of form deserve names, for convenient reference. Thus we have the great Kittatinny or Cumberland highland, C, C, on the southeast, backed by the older mountains of Cambrian and Archean rocks, falling by the Kittatinny slope to the synclinal lowland troughs of the central district. In this lower ground lay the synclinal troughs of the eastern coal regions, and the more local Broad Top basin, BT, on the southwest, then better than now deserving the name of basins. Beyond the corrugated area that connected the coal basins rose the great Nittany highland, N,

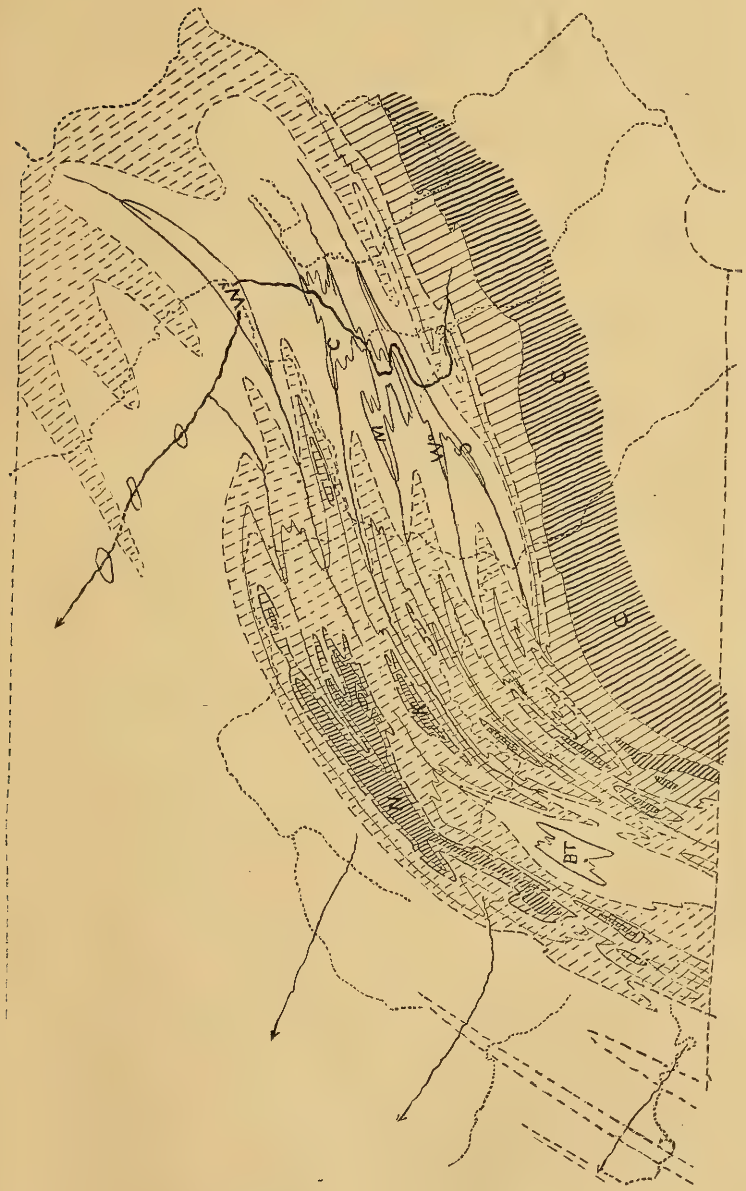


Fig. 21. Constructional Permian topography of Pennsylvania.

and its southwest extension in the Bedford range, with the less conspicuous Kishicoquilas highland, K, in the foreground. Beyond all stretched the great Alleghany lowland plains. The names thus suggested are compounded of the local names of to-day and the morphological names of Permian time.

What would be the drainage of such a country? Deductively we are led to believe that it consisted of numerous streams as marked in full lines on the figure, following synclinal axes until some master streams led them across the intervening anticlinal ridges at the lowest points of their crests and away into the open country to the northwest. All the enclosed basins would hold lakes, overflowing at the lowest part of the rim. The general discharge of the whole system would be to the northwest. Here again we must resort to special names for the easy indication of these well-marked features of the ancient and now apparently lost drainage system. The master stream of the region is the great Anthracite river, carrying the overflow of the Anthracite lakes off to the northwest and there perhaps turning along one of the faintly marked synclines of the plateau and joining the original Ohio, which was thus confirmed in its previous location across the Carboniferous marshes. The synclinal streams that entered the Anthracite lakes from the southwest may be named, beginning on the south, the Swatara, S, fig. 21, the Wiconisco, Wo, the Tuscarora-Mahanoy, M, the Juniata-Catawissa, C, and the Wyoming, Wy. One of these, probably the fourth, led the overflow from the Broad Top lake into the Catawissa lake on the middle Anthracite river. The Nittany highland formed a strong divide between the central and northwestern rivers, and on its outer slope there must have been streams descending to the Alleghany lowlands; and some of these may be regarded as the lower courses of Carboniferous rivers, that once rose in the Archean mountains, now beheaded by the growth of mountain ranges across their middle.

26. *The Jura mountains homologous with the Permian Alleghanies.*—However willing one may be to grant the former existence of such a drainage system as the above, an example of a similar one still in existence would be acceptable as a witness to the possibilities of the past. Therefore we turn for a moment to the Jura mountains, always compared to the Appalachians on account of the regular series of folds by which the two are characterized. But while the initial topography is long lost in our old mountains, it is still clearly perceptible in the young Jura,

where the anticlines are still ridges and the longitudinal streams still follow the synclinal troughs; while the transverse streams cross from one synclinal valley to another at points where the intervening anticlinal arches are lowest.* We could hardly ask for better illustration of the deductive drainage system of our early Appalachians than is here presented.

27. *Development and adjustment of the Permian drainage.*—The problem is now before us. Can the normal sequence of changes in the regular course of river development, aided by the post-Permian deformations and elevations, evolve the existing rivers out of the ancient ones?

In order to note the degree of comparison that exists between the two, several of the larger rivers of to-day are dotted on the figure. The points of agreement are indeed few and small. Perhaps the most important ones are that the Broad Top region is drained by a stream, the Juniata, which for a short distance follows near the course predicted for it; and that the Nittany district, then a highland, is still a well-marked divide although now a lowland. But there is no Anthracite river, and the region of the ancient coal-basin lakes is now avoided by large streams; conversely, a great river—the Susquehanna—appears where no consequent river ran in Permian time, and the early synclinal streams frequently turn from the structural troughs to valleys located on the structural arches.

28. *Lateral water gaps near the apex of synclinal ridges.*—One of the most frequent discrepancies between the hypothetical and actual streams is that the latter never follow the axis of a descending syncline along its whole length, as the original streams must have done, but depart for a time from the axis and then return to it, notching the ridge formed on any hard bed at the side instead of at the apex of its curve across the axis of the syncline. There is not a single case in the state of a stream cutting a gap at the apex of such a synclinal curve, but there are perhaps hundreds of cases where the streams notch the curve to one side of the apex. This, however, is precisely the arrangement attained by spontaneous adjustment from an initial axial course, as indicated in figure 13. The gaps may be located on small transverse faults, but as a rule they seem to have no such guidance. It is true that most of our streams now run out of and not into the

* This is beautifully illustrated in the recent monograph by La Noë and Margerie on "Les Formes du Terrain."

synclinal basins, but a reason for this will be found later ; for the present we look only at the location of the streams, not at their direction of flow. As far as this illustration goes, it gives evidence that the smaller streams at least possess certain peculiarities that could not be derived from persistence in a previous accidental location, but which would be necessarily derived from a process of adjustment following the original establishment of strictly consequent streams. Hence the hypothesis that these smaller streams were long ago consequent on the Permian folding receives confirmation ; but this says nothing as to the origin of the larger rivers, which might at the same time be antecedent.

29. *Departure of the Juniata from the Juniata-Catawissa syncline.*—It may be next noted that the drainage of the Broad Top region does not follow a single syncline to the Anthracite region, as it should have in the initial stage of the consequent Permian drainage, but soon turns aside from the syncline in which it starts and runs across country to the Susquehanna. It is true that in its upper course the Juniata departs from the Broad Top region by one of the two synclines that were indicated as the probable line of discharge of the ancient Broad Top lake in our restoration of the constructional topography of the State ; there does not appear to be any significant difference between the summit altitudes of the Tuscarora-Mahanoy and the Juniata-Catawissa synclinal axes and hence the choice must have been made for reasons that cannot be detected ; or it may be that the syncline lying more to the northwest was raised last, and for this reason was taken as the line of overflow. The beginning of the river is therefore not discordant with the hypothesis of consequent drainage, but the southward departure from the Catawissa syncline at Lewistown remains to be explained. It seems to me that some reason for the departure may be found by likening it to the case already given in figs. 16–18. The several synclines with which the Juniata is concerned have precisely the relative attitudes that are there discussed. The Juniata-Catawissa syncline has parallel sides for many miles about its middle, and hence must have long maintained the initial Juniata well above baselevel over all this distance ; the progress of cutting down a channel through all the hard Carboniferous standstones for so great a distance along the axis must have been exceedingly slow. But the synclines next south, the Tuscarora-Mahanoy and the Wiconisco, plunge to the northeast more rapidly, as the rapid

divergence of their margins demonstrates, and must for this reason have carried the hard sandstones below baselevel in a shorter distance and on a steeper slope than in the Catawissa syncline. The further southwestward extension of the Pocono sandstone ridges in the southern than in the northern syncline gives further illustration of this peculiarity of form. Lateral capture of the Juniata by a branch of the initial Tuscarora, and of the latter by a branch of the Wiconisco therefore seems possible, and the accordance of the facts with so highly specialized an arrangement is certainly again indicative of the correctness of the hypothesis of consequent drainage, and this time in a larger stream than before. At first sight, it appears that an easier lateral capture might have been made by some of the streams flowing from the outer slope of the Nittany highland; but this becomes improbable when it is perceived that the heavy Medina sandstone would here have to be worn through as well as the repeated arches of the Carboniferous beds in the many high folds of the Seven Mountains. Again, as far as present appearances go, we can give no sufficient reason to explain why possession of the headwaters of the Juniata was not gained by some subsequent stream of its own, such as G, fig. 18, instead of by a side-stream of the river in the neighboring syncline; but it may be admitted, on the other hand, that as far as we can estimate the chances for conquest, there was nothing distinctly in favor of one or the other of the side-streams concerned; and as long as the problem is solved indifferently in favor of one or the other, we may accept the lead of the facts and say that some control not now apparent determined that the diversion should be, as drawn, through D and not through G. The detailed location of the Juniata in its middle course below Lewistown will be considered in a later section.

30. *Avoidance of the Broad Top basin by the Juniata headwaters.*—Another highly characteristic change that the Juniata has suffered is revealed by examining the adjustments that would have taken place in the general topography of the Broad Top district during the Perm-Triassic cycle of erosion. When the basin, BT, fig. 22, was first outlined, centripetal streams descended its slopes from all sides and their waters accumulated as a lake in the center, overflowing to the east into the subordinate basin, A, in the Juniata syncline along side of the larger basin, and thence escaping northeast. In due time, the

breaching of the slopes opened the softer Devonian rocks beneath and peripheral lowlands were opened on them. The process by which the Juniata departed from its original axial location, J, fig. 22, to a parallel course on the southeastern side of the syncline, J, fig. 23, has been described (fig. 18). The subsequent changes are manifest. Some lateral branch of the Juniata, like N, fig. 23, would work its way around the northern end of the Broad Top canoe on the soft underlying rocks and capture the axial stream, C, that came from the depression between Nittany and Kishicoquillas highlands; thus reënforced, capture would be made of a radial stream from the west, Tn, the existing Tyrone branch of the Juniata; in a later stage the other streams of the western side of the basin would be acquired, their divertor constituting the Little Juniata of to-day; and the end would be when the original Juniata, A, fig. 22, that once issued from the subordinate synclinal as a large stream, had lost all its western tributaries, and was but a shrunken beheaded remnant of a river, now seen in Aughwick creek, A, fig. 24. In the meantime, the

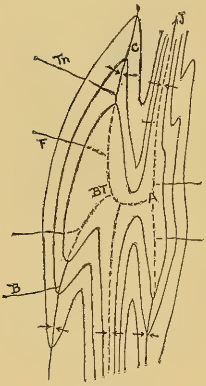


FIG. 22.

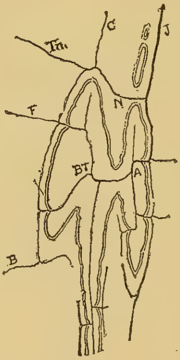


FIG. 23.

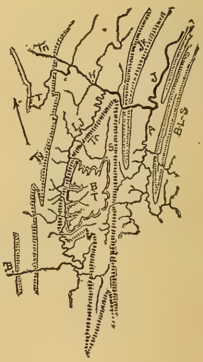


FIG. 24.

former lake basin was fast becoming a synclinal mountain of diminishing perimeter. The only really mysterious courses of the present streams are where the Little Juniata runs in and out of the western border of the Broad Top synclinal, and where the Frankstown (FT) branch of the Juniata maintains its independent gap across Tussey's mountain (Medina), although diverted to the Tyrone or main Juniata (Tn) by Warrior's ridge (Oriskany) just below. At the time of the early predatory growth of the initial divertor, N, its course lay by the very conditions of its growth on only the weakest rocks ; but after this little stream had grown to a good-sized river, further rising of the land, probably in the time of the Jurassic elevation, allowed the river to sink its channel to a greater depth, and in doing so, it encountered the hard Medina anticline of Jack's mountain ; here it has since persisted, because, as we may suppose, there has been no stream able to divert the course of so large a river from its crossing of a single hard anticlinal.

The doubt that one must feel as to the possibility of the processes just outlined arises, if I may gauge it by my own feeling, rather from incredulity than from direct objections. It seems incredible that the waste of the valley slopes should allow the backward growth of N at such a rate as to enable it to capture the heads of C, Tn, F, and so on, before they had cut their beds down close enough to the baselevel of the time to be safe from capture. But it is difficult to urge explict objections against the process or to show its quantitative insufficiency. It must be remembered that when these adjustments were going on, the region was one of great altitude, its rocks then had the same strong contrasts of strength and weakness that are so apparent in the present relief of the surface and the streams concerned were of moderate size ; less than now, for at the time, the Tyrone, Frankstown and Bedford head branches of the Juniata had not acquired drainage west of the great Nittany-Bedford anticlinal axis, but were supplied only by the rainfall on its eastern slope (see section 39)—and all these conditions conspired to favor the adjustment. Finally, while apparently extraordinary and difficult of demonstration, the explanation if applicable at all certainly gives rational correlation to a number of peculiar and special stream courses in the upper Juniata district that are meaningless under any other theory that has come to my notice. It is chiefly for this reason that I am inclined to accept the explanation.

31. *Reversal of larger rivers to southeast courses.*—Our large rivers at present flow to the southeast, not to the northwest. It is difficult to find any precise date for this reversal of flow from the initial hypothetical direction, but it may be suggested that it occurred about the time of the Triassic depression of the Newark belt. We have been persuaded that much time elapsed between the Permian folding and the Newark deposition, even under the most liberal allowance for pre-Permian erosion in the Newark belt ; hence when the depression began, the rivers must

have had but moderate northwestward declivity. The depression and submergence of the broad Newark belt may at this time have broken the continuity of the streams that once flowed across it. The headwater streams from the ancient Archean country maintained their courses to the depression; the lower portions of the rivers may also have gone on as before; but the middle courses were perhaps turned from the central part of the state back of the Newark belt. No change of attitude gives so fitting a cause of the southeastward flow of our rivers as this. The only test that I have been able to devise for the suggestion is one that is derived from the relation that exists between the location of the Newark belt along the Atlantic slope and the course of the neighboring transverse rivers. In Pennsylvania, where the belt reaches somewhat beyond the northwestern margin of the crystalline rocks in South mountain, the streams are reversed, as above stated; but in the Carolinas where the Newark belt lies far to the east of the boundary between the Cambrian and crystalline rocks, the Tennessee streams persevere in what we suppose to have been their original direction of flow. This may be interpreted as meaning that in the latter region, the Newark depression was not felt distinctly enough, if at all, within the Alleghany belt to reverse the flow of the streams; while in the former region, it was nearer to these streams and determined a change in their courses. The original Anthracite river ran to the northwest, but its middle course was afterwards turned to the southeast.

I am free to allow that this has the appearance of heaping hypothesis on hypothesis; but in no other way does the analysis of the history of our streams seem possible, and the success of the experiment can be judged only after making it. At the same time, I am constrained to admit that this is to my own view the least satisfactory of the suggestions here presented. It may be correct, but there seems to be no sufficient exclusion of other possibilities. For example, it must not be overlooked that, if the Anthracite river ran southeast during Newark deposition, the formation of the Newark northwestward monocline by the Jurassic tilting would have had a tendency to turn the river back again to its northwest flow. But as the drainage of the region is still southeastward, I am tempted to think that the Jurassic tilting was not here strong enough to reverse the flow of so strong and mature a river as the Anthracite had by that time come to be ; and that the elevation that accompanied the tilting was not so powerful in reversing the river to a northwest course as the previous depression of the Newark basin had been in turning it to the southeast. If the Anthracite did continue to flow to the southeast, it may be added that the down-cutting of its upper branches was greatly retarded by the decrease of slope in its lower course when the monocline was formed.

The only other method of reversing the original northwestward flow of the streams that I have imagined is by capture of their headwaters by Atlantic rivers. This seems to me less effective than the method just considered ; but they are not mutually exclusive and the actual result may be the sum of the two processes. The outline of the idea is as follows. The long continued supply of sedimentary material from the Archean land on the southeast implies that it was as continually elevated. But there came a time when there is no record of further supply of material, and when we may therefore suppose the elevation was no longer maintained. From that time onward, the Archean range must have dwindled away, what with the encroachment of the Atlantic on its eastern shore and the general action of denuding forces on its surface. The Newark depression was an effective aid to the same end, as has been stated above, and for a moderate distance westward of the depressed belt, the former direction of the streams must certainly have been reversed ; but the question remains whether this reversal extended as far as the Wyoming basin, and whether the subsequent formation of the Newark monocline did not undo the effect of the Newark depression. It is manifest that as far as our limited knowledge goes, it is impossible to estimate these matters quantitatively, and hence the importance of looking for additional processes that may supplement the effect of the Newark depression and counteract the effect of the Newark uplift in changing the course of the rivers. Let it be supposed for the moment that at the end of the Jurassic uplift by which the Newark monocline was formed, the divide between the Ohio and the Atlantic drainage lay about the middle of the Newark belt. There was a long gentle descent westward from this watershed and a shorter and hence steeper descent eastward. Under such conditions, the divide must have been pushed westward, and as long as the rocks were so exposed as to open areas of weak sediments on which capture by the Atlantic streams could go on with relative rapidity, the westward migration of the divide would be important. For this reason, it might be carried from the Newark belt as far as the present Alleghany front, beyond which further pushing would be slow, on account of the broad stretch of country there covered by hard horizontal beds.

The end of this is that, under any of the circumstances here detailed, there would be early in the Jurassic-Cretaceous cycle a distinct tendency to a westward migration of the Atlantic-Ohio divide; it is the consequences of this that have now to be examined.

32. *Capture of the Anthracite headwaters by the growing Susquehanna.*—Throughout the Perm-Triassic period of denudation, a great work was done in wearing down the original Alleghanies. Anticlines of hard sandstone were breached, and broad lowlands were opened on the softer rocks beneath. Little semblance of the early constructional topography remained when the period of Newark depression was brought to a close; and all the while the headwater streams of the region were gnawing at the divides, seeking to develop the most perfect arrangement of waterways. Several adjustments have taken place, and the larger streams have been reversed in the direction of their flow; but a more serious problem is found in the disappearance of the original master stream, the great Anthracite river, which must have at first led away the water from all the lateral synclinal streams. Being a large river, it could not have been easily diverted from its course, unless it was greatly retarded in cutting down its channel by the presence of many beds of hard rocks on its way. The following considerations may perhaps throw some light on this obscure point.

It may be assumed that the whole group of mountains formed by the Permian deformation had been reduced to a moderate relief when the Newark deposition was stopped by the Jurassic elevation. The harder ribs of rock doubtless remained as ridges projecting above the intervening lowlands, but the strength of relief that had been given by the constructional forces had been lost. The general distribution of residual elevations then remaining unsubdued is indicated in fig. 25, in which the Crystalline, the Medina, and the two Carboniferous sandstone ridges are denoted by appropriate symbols. In restoring this phase of the surface form, when the country stood lower than now, I have reduced the anticlines from their present outlines and increased the synclines, the change of area being made

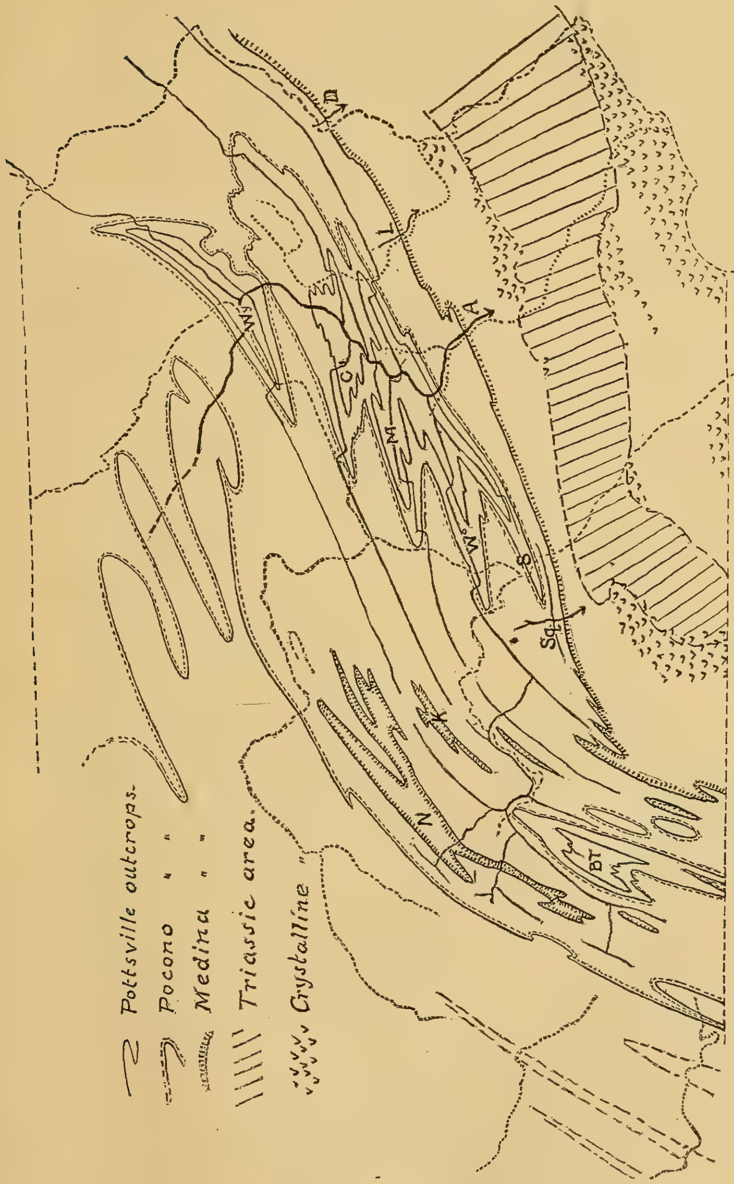


FIG. 25. General distribution of high and low land and drainage in early Jurassic time.

greatest where the dips are least, and hence most apparent at the ends of the plunging anticlines and synclines. Some of the Medina anticlines of Perry and Juniata counties are not indicated because they were not then uncovered. The country between the residual ridges of Jurassic time was chiefly Cambrian limestone and Siluro-Devonian shales and soft sandstones. The moderate ridges developed on the Oriskany and Chemung sandstones are not represented. The drainage of this stage retained the original courses of the streams, except for the adjustments that have been described, but the great Anthracite river is drawn as if it had been controlled by the Newark depression and reversed in the direction of its flow, so that its former upper course on the Cambrian rocks was replaced by a superimposed Newark lower course. Fig. 25 therefore represents the streams for the most part still following near their synclinal axes, although departing from them where they have to enter a synclinal cove-mountain ridge ; the headwaters of the Juniata avoid the mass of hard sandstones discovered in the bottom of old Broad Top lake, and flow around them to the north, and then by a cross-country course to the Wiconisco synclinal, as already described in detail. Several streams come from the northeast, entering the Anthracite district after the fashion generalized in fig. 13. Three of the many streams that were developed on the great Kittatinny slope are located, with their direction of flow reversed; these are marked Sq, L and D, and are intended to represent the ancestors of the existing Susquehanna, Lehigh and Delaware. We have now to examine the opportunities offered to these small streams to increase their drainage areas.

The Jurassic elevation, by which the Newark deposition was stopped, restored to activity all the streams that had in the previous cycle sought and found a course close to baselevel. They now all set to work again deepening their channels. But in this restoration of lost activity with reference to a new baselevel, there came the best possible chance for numerous re-arrangements of drainage areas by mutual adjustment into which we must inquire.

I have already illustrated what seems to me to be the type of the conditions involved at this time in figs. 19 and 20. The master stream, A, traversing the synclines, corresponds to the reversed Anthracite river ; the lowlands at the top are those that have been opened out on the Siluro-Devonian beds of the present Susquehanna middle course between the Pocono and the Medina ridges. The small stream, B, that is gaining drainage area in these lowlands, corresponds to the embryo of the present Susquehanna, Sq, fig. 25, this having been itself once a branch on the south side of the Swatara synclinal stream, fig. 21, from which it was first turned by the change of slope accompanying the Newark depression ; but it is located a little farther west than the actual Susquehanna, so as to avoid the two synclinal cove mountains of Pocono sandstone that the Susquehanna now traverses, for reasons to be stated below (section 35). This stream had to cross only one bed of hard rock, the outer wall of Medina sandstone, between the broad inner lowlands of the relatively weak Siluro-Devonian rocks and the great valley lowlands on the still weaker Cambrian limestones. Step by step it must have pushed its headwater divide northward, and from time to time it would have thus captured a subsequent stream, that crossed the lowlands eastward, and entered a Carboniferous syncline by one of the lateral gaps already described. With every such capture, the power of the growing stream to capture others was increased. Fig. 19 represents a stage after the streams in the Swatara and Wiconisco synclines (the latter then having gained the Juniata) had been turned aside on their way to the Carboniferous basins. On the other hand, the Anthracite river, rising somewhere on the plains north of the Wyoming syncline and pursuing an irregular course from one coal basin to another, found an extremely difficult task in cutting down its channel across the numerous hard beds of the Carboniferous sandstones, so often repeated in the rolling folds of the coal fields. It is also important to remember that an aid to other conditions concerned in the diversion of the upper Anthracite is found in the decrease of slope that its lower course suffered in crossing the coal fields, if that area took any part in the deformation that produced the Newark monocline—whichever theory prove true in regard to the origin of the southeastward flow of the rivers—for loss of slope in the middle course, where the river had to cross many reefs of hard sandstone, would have been very effective in lengthening the time allowed for the diversion of the headwaters.

The question is, therefore, whether the retardation of downcutting here experienced by the Anthracite was sufficient to allow the capture of its headwaters by the Susquehanna. There can be little doubt as to the correct quality of the process, but whether it was quantitatively sufficient is another matter. In the absence of any means of testing its sufficiency, may the result not be taken as the test? Is not the correspondence between deduction and fact close enough to prove the correctness of the deduction?

33. *Present outward drainage of the Anthracite basins.*—The Lehigh, like the Susquehanna, made an attempt to capture the headwaters of adjacent streams, but failed to acquire much territory from the Anthracite because the Carboniferous sandstones spread out between the two in a broad plateau of hard rocks, across which the divide made little movement. The plateau area that its upper branches drain is, I think, the conquest of a later cycle of growth. The Delaware had little success, except as against certain eastern synclinal branches of the Anthracite, for the same reason. The ancestor of the Swatara of to-day made little progress in extending its headwaters because its point of attack was against the repeated Carboniferous sandstones in the Swatara synclinal. One early stream alone found a favorable opportunity for conquest, and thus grew to be the master river—the Susquehanna of to-day. The head of the Anthracite was carried away by this captor, and its beheaded lower portion remains in our Schuylkill. The Anthracite coal basins, formerly drained by the single master stream, have since been apportioned to the surrounding rivers. As the Siluro-Devonian lowlands were opened around the coal-basins, especially on the north and west, the streams that formerly flowed into the basins were gradually inverted and flowed out of them, as they still do. The extent of the inversion seems to be in a general way proportionate to its opportunity. The most considerable conquests were made in the upper basins, where the Catawissa and Nescopec streams of to-day drain many square miles of wide valleys opened on the Mauch Chunk red shale between the Pocono and Pottsville sandstone ridges; the ancient middle waters of the Anthracite here being inverted to the Susquehanna tributaries, because the northern coal basins were degraded very slowly after the upper Anthracite had been diverted. The Schuylkill as the modern representative of the Anthracite retains only certain streams south of a medial divide between Nescopec and Blue mountains. The only considerable part of the old Anthracite river that still retains a course along the axis of a synclinal trough seems to be that part which follows the Wyoming basin; none of the many other

coal basins are now occupied by the large stream that originally followed them. The reason for this is manifestly to be found in the great depth of the Wyoming basin, whereby the axial portion of its hard sandstones are even now below baselevel, and hence have never yet acted to throw the river from its axial course. Indeed, during the early cycles of denudation, this basin must have been changed from a deep lake to a lacustrine plain by the accumulation in it of waste from the surrounding highlands, and for a time the streams that entered it may have flowed in meandering courses across the ancient alluvial surface ; the lacustrine and alluvial condition may have been temporarily revived at the time of the Jurassic elevation. It is perhaps as an inheritance from a course thus locally superimposed that we may come to regard the deflection of the river at Nanticoke from the axis of the syncline to a narrow shale valley on its northern side, before turning south again and leaving the basin altogether. But like certain other suggestions, this can only be regarded as an open hypothesis, to be tested by some better method of river analysis than we now possess ; like several of the other explanations here offered, it is presented more as a possibility to be discussed than as a conclusion to be accepted.

I believe that it was during the earlier part of the great Jura-Cretaceous cycle of denudation that the Susquehanna thus became the master stream of the central district of the state. For the rest of the cycle, it was occupied in carrying off the waste and reducing the surface to a well finished baselevel lowland that characterized the end of Cretaceous time. From an active youth of conquest, the Susquehanna advanced into an old age of established boundaries ; and in later times, its area of drainage does not seem to have been greatly altered from that so long ago defined ; except perhaps in the districts drained by the West and North Branch headwaters.

34. *Homologies of the Susquehanna and Juniata.*—Looking at the change from the Anthracite to the Susquehanna in a broad way, one may perceive that it is an effect of the same order as the peripheral diversion of the Broad Top drainage, illustrated in figures 22, 23 and 24 ; another example of a similar change is seen in the lateral diversion of the Juniata above Lewistown and its rectilinear continuation in Aughwick creek, from their original axial location when they formed the initial Broad Top outlet. They have departed from the axis of their syncline to

the softer beds on its southern side; FE of fig. 17 has been diverted to FD of fig. 18.

All of these examples are truly only special cases of the one already described in which the Juniata left its original syncline for others to the south. The general case may be stated in a few words. A stream flowing along a syncline of hard beds (Carboniferous sandstones) developes side streams which breach the adjacent anticlines and open lowlands in the underlying softer beds (Devonian and Silurian). On these lowlands, the headwaters of side streams from other synclines are encountered and a contest ensues as to possession of the drainage territory. The divides are pushed away from those headwaters whose lower course leads them over the fewest hard barriers; this conquest goes on until the upper course of the initial main stream is diverted to a new and easier path than the one it chose in its youth in obedience to the first deformation of the region. Thus the Juniata now avoids the center and once deepest part of the old Broad Top lake, because in the general progress of erosion, lowlands on soft Devonian beds were opened all around the edge of the great mass of sandstones that held the lake; the original drainage across the lake, from its western slopes to its outlet just south of the Jack's mountain anticline, has now taken an easier path along the Devonian beds to the west of the old lake basin, and is seen in the Little Juniata, flowing along the outer side of Terrace mountain and rounding the northern synclinal point where Terrace mountain joins Sideling hill. It then crosses Jack's mountain at a point where the hard Medina sandstones of the mountain were still buried at the time of the choice of this channel. In the same way, the drainage of the subordinate basin, through which the main lake discharged eastward, is now not along the axis of the Juniata-Catawissa syncline, but on the softer beds along one side of it; and along the southern side because the easier escape that was provided for it lay on that side, namely, via the Tuscarora and Wiconisco synclines, as already described. The much broader change from the Anthracite to the Susquehanna was only another form of the same process. Taking a transverse view of the whole system of central folds, it is perceived that their axes descend into the Anthracite district from the east and rise westward therefrom; it is as if the whole region had received a slight transverse folding, and the transverse axis of depression thus formed defined the initial course of the first master stream.

But this master stream deserted its original course on the transverse axis of depression because a lateral course across lowlands on softer beds was opened by its side streams ; and in the contest on these lowlands with an external stream, the Susquehanna, the upper portion of the Anthracite was diverted from the hard rocks that had appeared on the transverse axis. The distance of diversion from the axial to the lateral course in this case was great because of the gentle quality of the transverse folding ; or, better said, because of the gentle dips of the axes of the longitudinal folds. This appearance of systematic re-arrangement in the several river courses where none was expected is to my mind a strong argument in favor of the originally consequent location of the rivers and their later mutual adjustment. It may perhaps be conceived that antecedent streams might imitate one another roughly in the attitude that they prophetically chose with regard to folds subsequently formed, but no reason has been suggested for the imitation being carried to so remarkable and definite a degree as that here outlined.

35. *Superimposition of the Susquehanna on two synclinal ridges.*—There is however one apparently venturesome postulate that may have been already noted as such by the reader ; unless it can be reasonably accounted for and shown to be a natural result of the long sequence of changes here considered, it will seriously militate against the validity of the whole argument. The present course of the middle Susquehanna leads it through the apical curves of two Pocono synclinal ridges, which were disregarded in the statement given above. It was then assumed that the embryonic Susquehanna gained possession of the Siluro-Devonian lowland drainage by gnawing out a course to the west of these synclinal points ; for it is not to be thought of that any conquest of the headwaters of the Anthracite river could have been made by the Susquehanna if it had had to gnaw out the existing four traverses of the Pocono sandstones before securing the drainage of the lowlands above them. The backward progress of the Susquehanna could not in that case have been nearly fast enough to reach the Anthracite before the latter had sunk its channel to a safe depth. It is therefore important to justify the assumption as to the more westerly location of the embryonic Susquehanna ; and afterwards to explain how it should have since then been transferred to its present course. A short cut through all this round-about method is open to those who adopt

in the beginning the theory that the Susquehanna was an antecedent river; but as I have said at the outset of this inquiry, it seems to me that such a method is not freer from assumption, even though shorter than the one here adopted; and it has the demerit of not considering all the curious details that follow the examination of consequent and adjusted courses.

The sufficient reason for the assumption that the embryonic Susquehanna lay farther west than the present one in the neighborhood of the Pocono synclinals is simply that—in the absence of any antecedent stream—it must have lain there. The whole explanation of the development of the Siluro-Devonian lowlands between the Pocono and Medina ridges depends simply on their being weathered out where the rocks are weak enough to waste faster than the enclosing harder ridges through which the streams escape. In this process, the streams exercise no control whatever over the direction in which their headwaters shall grow; they leave this entirely to the structure of the district that they drain. It thus appears that, under the postulate as to the initial location of the Susquehanna as one of the many streams descending the great slope of the Kittatinny (Cumberland) highland into the Swatara syncline, its course being reversed from northward to southward by the Newark depression, we are required to suppose that its headwater (northward) growth at the time of the Jurassic elevation must have been on the Siluro-Devonian beds, so as to avoid the harder rocks on either side. Many streams competed for the distinction of becoming the master, and that one gained its ambition whose initial location gave it the best subsequent opportunity. It remains then to consider the means by which the course of the conquering Susquehanna may have been subsequently changed from the lowlands on to the two Pocono synclines that it now traverses. Some departure from its early location may have been due to eastward planation in its advanced age, when it had large volume and gentle slope and was therefore swinging and cutting laterally in its lower course. This may have had a share in the result, but there is another process that seems to me more effective.

In the latter part of the Jura-Cretaceous cycle, the whole country hereabout suffered a moderate depression, by which the Atlantic transgressed many miles inland from its former shoreline, across the lowlands of erosion that had been developed on the litoral belt. Such a depression must have had a distinct effect on the lower courses of the larger rivers, which having already cut their channels down close to baselevel and opened their valleys wide on the softer rocks, were then "estuaried," or at least so far checked as to build wide flood-plains over their lower stretches. Indeed, the flood-plains may have been begun at an earlier date, and have been confirmed and extended in the later time of depression. Is it possible that in the latest stage of this process, the almost baselevelled remnants of Blue mountain and the Pocono ridges could have been buried under the flood-plain in the neighborhood of the river?

If this be admitted, it is then natural for the river to depart from the line of its buried channel and cross the buried ridges on which it might settle down as a superimposed river in the next cycle of elevation. It is difficult to decide such general questions as these; and it may be difficult for the reader to gain much confidence in the efficacy of the processes suggested; but there are certain features in the side streams of the Susquehanna that lend some color of probability to the explanation as offered.

Admit, for the moment, that the aged Susquehanna, in the later part of the Jura-Cretaceous cycle, did change its channel somewhat by cutting to one side, or by planation, as it is called. Admit, also, that in the natural progress of its growth it had built a broad flood plain over the Siluro-Devonian lowlands, and that the depth of this deposit was increased by the formation of an estuarine delta upon it when the country sank at the time of the mid-Cretaceous transgression of the sea. It is manifest that one of the consequences of all this might be the peculiar course of the river that is to be explained, namely, its superimposition on the two Pocono synclinal ridges in the next cycle of its history, after the Tertiary elevation had given it opportunity to re-discover them. It remains to inquire what other consequences should follow from the same conditions, and from these to devise tests of the hypothesis.

36. *Evidence of superimposition in the Susquehanna tributaries.*—One of the peculiarities of flood-plained rivers is that the lateral streams shift their points of union with the main stream farther and farther down the valley, as Lombardini has shown in the case of the Po. If the Susquehanna were heavily flood-plained at the close of the Jura-Cretaceous cycle, some of its tributaries should manifest signs of this kind of deflection from their structural courses along the strike of the rocks. Side

streams that once joined the main stream on the line of some of the softer northeast-southwest beds, leaving the stronger beds as faint hills on either side, must have forgotten such control after it was baselevelled and buried; as the flood plain grew, they properly took more and more distinctly downward deflected courses, and these deflections should be maintained in subsequent cycles as superimposed courses independent of structural guidance. Such I believe to be the fact. The downstream deflection is so distinctly a peculiarity of a number of tributaries that join the Susquehanna on the west side (see figure 1) that it cannot be ascribed to accident, but must be referred to some systematic cause. Examples of deflection are found in Penn's creek, Middle creek and North Mahantango creek in Snyder county; West Mahantango between the latter and Juniata county; and in the Juniata and Little Juniata rivers of Perry county. On the other side of the Susquehanna, the examples are not so distinct, but the following may be mentioned: Delaware and Warrior runs, Chillisquaque creek and Little Shamokin creek, all in Northumberland county. It may be remarked that it does not seem impossible that the reason for the more distinct deflection of the western streams may be that the Susquehanna is at present east of its old course, and hence towards the eastern margin of its flood plain, as, indeed its position on the Pocono synclinals implies. A reason for the final location of the superimposed river on the eastern side of the old flood plain may perhaps be found in the eastward tilting that is known to have accompanied the elevation of the Cretaceous lowland.

It follows from the foregoing that the present lower course of the Susquehanna must also be of superimposed origin; for the flood plain of the middle course must have extended down stream to its delta, and there have become confluent with the sheet of Cretaceous sediments that covered all the southeastern lowland, over which the sea had transgressed. McGee has already pointed out indications of superimposed stream courses in the southeastern part of the State;* but I am not sure that he would regard them as of the date here referred to.

The theory of the location of the Susquehanna on the Pocono synclinal ridges therefore stands as follows. The general position of the river indicates that it has been located by some process of slow self-adjusting development and that it is not a persistent

* Amer. Journ. Science, xxxv, 1888, 121, 134.

antecedent river ; and yet there is no reason to think that it could have been brought into its present special position by any process of shifting divides. The processes that have been suggested to account for its special location, as departing slightly from a location due to slow adjustments following an ancient consequent origin, call for the occurrence of certain additional peculiarities in the courses of its tributary streams, entirely unforeseen and unnoticed until this point in the inquiry is reached ; and on looking at the map to see if they occur, they are found with perfect distinctness. The hypothesis of superimposition may therefore be regarded as having advanced beyond the stage of mere suggestion and as having gained some degree of confirmation from the correlations that it detects and explains. It only remains to ask if these correlations might have originated in any other way, and if the answer to this is in the negative, the case may be looked upon as having a fair measure of evidence in its favor. The remaining consideration may be taken up at once as the first point to be examined in the Tertiary cycle of development.

37. *Events of the Tertiary cycle.*—The elevation given to the region by which Cretaceous baselevelling was terminated, and which I have called the early Tertiary elevation, offered opportunity for the streams to deepen their channels once more. In doing so, certain adjustments of moderate amount occurred, which will be soon examined. As time went on, much denudation was effected, but no wide-spread baselevelling was reached, for the Cretaceous crest lines of the hard sandstone ridges still exist. The Tertiary cycle was an incomplete one. At its close, lowlands had been opened only on the weaker rocks between the hard beds. Is it not possible that the flood-plaining of the Susquehanna and the down-stream deflection of its branches took place in the closing stages of this cycle, instead of at the end of the previous cycle? If so, the deflection might appear on the branches, but the main river would not be transferred to the Pocono ridges. This question may be safely answered in the negative ; for the Tertiary lowland is by no means well enough baselevelled to permit such an event. The beds of intermediate resistance, the Oriskany and certain Chemung sandstones, had not been worn down to baselevel at the close of the Tertiary cycle ; they had indeed lost much of the height that they possessed at the close of the previous cycle, but they had not been reduced as low as the softer beds on either side. They were only reduced to ridges of

moderate and unequal height over the general plain of the Siluro-Devonian low country, without great strength of relief but quite strong enough to call for obedience from the streams along side of them. And yet near Selin's Grove, for example, in Snyder county, Penn's and Middle creeks depart most distinctly from the strike of the local rocks as they near the Susquehanna, and traverse certain well-marked ridges on their way to the main river. Such aberrant streams cannot be regarded as superimposed at the close of the incomplete Tertiary cycle ; they cannot be explained by any process of spontaneous adjustment yet described, nor can they be regarded as vastly ancient streams of antecedent courses ; I am therefore much tempted to consider them as of superimposed origin, inheriting their present courses from the flood-plain cover of the Susquehanna in the latest stage of the Jura-Cretaceous cycle. With this tentative conclusion in mind as to the final events of Jura-Cretaceous time, we may take up the more deliberate consideration of the work of the Tertiary cycle.

The chief work of the Tertiary cycle was merely the opening of the valley lowlands ; little opportunity for river adjustment occurred except on a small scale. The most evident cases of adjustment have resulted in the change of water-gaps into wind-gaps, of which several examples can be given, the one best known being the Delaware wind-gap between the Lehigh and Delaware water-gaps in Blue mountain. The wind-gap marks the unfinished notch of some stream that once crossed the ridge here and whose headwaters have since then been diverted, probably to the Lehigh. The difficulty in the case is not at all how the stream that once flowed here was diverted, but how a stream that could be diverted in the Tertiary cycle could have escaped diversion at some earlier date. The relative rarity of wind-gaps indicates that nearly all of the initial lateral streams, which may have crossed the ridges at an early epoch in the history of the rivers, have been beheaded in some cycle earlier than the Tertiary and their gaps thereafter obliterated. Why the Delaware wind-gap stream should have endured into a later cycle does not at present appear. Other wind-gaps of apparently similar origin may be found in Blue mountain west of the Schuylkill and east of the Susquehanna. It is noteworthy that if any small streams still persevere in their gaps across a hard ridge, they are not very close to any large river-gap ; hence it is only at the very headwaters of Conedogwinet creek, in the northern part of Franklin county, that any water is still drawn from the back of Blue mountain. Again, these small stream gaps do not lie between large river-gaps and wind-gaps, but wind-gaps lie between the gaps of large rivers and those of small streams that are not yet diverted. Excellent illustration of this is found on the "Piedmont sheet" of the contoured maps issued by the United States Geological Survey. The sheet covers part of Maryland and West Virginia, near where the North Branch of the Potomac comes out of the plateau and crosses New Creek mountain. Eleven miles south of the Potomac gap there is a deep wind-gap; but further on, at twenty, twenty-five and twenty-nine miles from the river-gap are three fine water-gaps occupied by small streams. This example merely shows how many important points in the history of our rivers will be made clear when the country is properly portrayed on contoured maps.

A few lines may be given to the general absence of gaps in Blue Mountain in Pennsylvania. When the initial consequent drainage was established, many streams must have been located on the northward slope of the great Cumberland highland, C, C, fig. 21; they must have gullied the slope to great depths and carried away great volumes of the weak Cambrian beds that lay deep within the hard outer casings of the mass. Minor adjustments served to diminish the number of these streams, but the more effective cause of their present rarity lay in the natural selection of certain of them to become large streams; the smaller ones were generally beheaded by these. The only examples of streams that still cross this ridge with their initial Permian direction of flow to the northwest are found in two southern branches of Tuscarora creek at the southern point of Juniata county; and these survive because of their obscure location among the many Medina ridges of that district, where they were not easily accessible to capture by other streams.

38. *Tertiary adjustment of the Juniata on the Medina anticlines.*—The lower course of the Juniata presents several examples of adjustment referable to the last part of the Jura-Cretaceous cycle and to the Tertiary cycle. The explanation offered for the escape of this river from its initial syncline did not show any reason for its peculiar position with respect to the several Medina anticlines that it now borders, because at the time when it was led across country to the Wiconisco syncline, the hard Medina beds of these anticlines were not discovered. It is therefore

hardly to be thought that the location of the Juniata in the Narrows below Lewistown between Blue Ridge and Shade mountain and its avoidance of Tuscarora mountain could have been defined at that early date. But all these Medina anticlines rise more or less above the Cretaceous baselevel, and must have had some effect on the position taken by the river about the middle of that cycle when its channel sank upon them. Blue Ridge and Black Log anticlines rise highest. The first location of the cross-country stream that led the early Juniata away from its initial syncline probably traversed the Blue Ridge and Black Log anticlines while they were yet buried; but its channel-cutting was much retarded on encountering them, and some branch stream working around from the lower side of the obstructions may have diverted the river to an easier path. The only path of the kind is the narrow one between the overlapping anticlines of Blue Ridge and Shade mountains, and there the Juniata now flows. If another elevation should occur in the future, it might happen that the slow deepening of the channel in the hard Medina beds which now floor the Narrows would allow Middle creek of Snyder county to tap the Juniata at Lewistown and lead it by direct course past Middleburgh to the Susquehanna; thus it would return to the path of its youth.

The location of the Juniata at the end of Tuscarora mountain is again so definite that it can hardly be referred to a time when the mountain had not been revealed. The most likely position of the original cross-country stream which brought the Juniata into the Wiconisco syncline was somewhere on the line of the existing mountain, and assuming it to have been there, we must question how it has been displaced. The process seems to have been of the same kind as that just given; the retardation of channel-cutting in the late Cretaceous cycle, when the Medina beds of Tuscarora anticline were discovered, allowed a branch from the lower part of the river to work around the end of the mountain and lead the river out that way. The occurrence of a shallow depression across the summit of the otherwise remarkably even crest of Tuscarora mountain suggests that this diversion was not finally accomplished until shortly after the Tertiary elevation of the country; but at whatever date the adjustment occurred, it is natural that it should pass around the eastern end of the mountain and not around the western end, where the course would have been much longer, and therefore not successfully to be taken by a diverting stream.

While the quality of these processes appears satisfactory, I am not satisfied as to the sufficiency of their quantity. If diversion was successfully practiced at the crossing of the Tuscarora anticline, why not also at the crossing of Jack's mountain anticline, on which the river still perseveres. It is difficult here to decide how much confidence may be placed in the explanation, because of its giving reason for the location of certain streams, and how much doubt must be cast upon it, because it seems impossible and is not of universal application.

39. *Migration of the Atlantic-Ohio divide.*—There are certain shifted courses which cannot be definitely referred to any particular cycle, and which may therefore be mentioned now. Among the greatest are those by which the divide between the Atlantic and the Ohio streams has been changed from its initial position on the great constructional Nittany highland and Bedford range. There was probably no significant change until after Newark depression, for the branches of the Anthracite river could not have begun to push the divide westward till after the eastward flow of the river was determined; until then, there does not seem to have been any marked advantage possessed by the eastward streams over the westward. But with the eastward escape of the Anthracite, it probably found a shorter course to the sea and one that led it over alternately soft and hard rocks, instead of the longer course followed by the Ohio streams over continuous sandstones. The advantage given by the greater extent of soft beds is indicated by the great breadth of the existing valleys in the central district compared with the less breadth of those in the plateau to the west. Consider the effect of this advantage at the time of the Jurassic elevation. As the streams on the eastern slope of the Nittany divide had the shortest and steepest courses to the sea, they deepened their valleys faster than those on the west and acquired drainage area from them; hence we find reason for the drainage of the entire Nittany and Bedford district by the Atlantic streams at present. Various branches of what are now the Alleghany and Monongahela originally rose on the western slope of the dividing range. These probably reached much farther east in pre-Permian time, but had their headwaters turned another way by the growth of the great anticlinal divide; but the smaller anticlines of Laurel ridge and Negro mountain farther west do not seem to have been strong enough to form a divide, for the rivers still traverse them. Now as the headwaters

of the Juniata breached the eastern slope of the Nittany-Bedford range and pushed the divide westward, they at last gained possession of the Siluro-Devonian monocline on its western slope; but beyond this it has not been possible for them yet to go. As the streams cut down deeper and encountered the Medina anticline near the core of the ridge, they sawed a passage through it; the Cambrian beds were discovered below and a valley was opened on them as the Medina cover wore away. The most important point about this is that we find in it an adequate explanation of the opposite location of water-gaps in pairs, such as characterize the branches of the Juniata below Tyrone and again below Bedford. This opposite location has been held to indicate an antecedent origin of the river that passes through the gaps, while gaps formed by self-developed streams are not thought to present such correspondence (Hilber). Yet this special case of paired gaps in the opposite walls of a breached anticline is manifestly a direct sequence of the development of the Juniata headwaters. The settling down of the main Juniata on Jack's mountain anticline below Huntingdon is another case of the same kind, in which the relatively low anticlinal crest is as yet not widely breached; the gaps below Bedford stand apart, as the crest is there higher, and hence wider opened; and the gaps below Tyrone are separated by some ten or twelve miles.

When the headwater streams captured the drainage of the Siluro-Devonian monocline on the western side of the ancient dividing anticline, they developed subsequent rectangular branches growing like a well-trained grape vine. Most of this valley has been acquired by the west branch of the Susquehanna, probably because it traversed the Medina beds less often than the Juniata. For the same reason, it may be, the West Branch has captured a considerable area of plateau drainage that must have once belonged to the Ohio, while the Juniata has none of it; but if so, the capture must have been before the Tertiary cycle, for since that time the ability of the West Branch and of the Juniata as regards such capture appears about alike. On the other hand, Castleman's river, a branch of the Monongahela, still retains the drainage of a small bit of the Siluro-Devonian monocline, at the southern border of the State, where the Juniata headwaters had the least opportunity to capture it; but the change here is probably only retarded, not prevented entirely; the Juniata will some day push the divide even here back to the Alleghany Front, the frontal bluff of the plateau.

40. *Other examples of adjustments.*—Other examples of small adjustments are found around the Wyoming basin, fig. 26.

FIG. 26.

Originally all these streams ran centripetally down the enclosing slopes, and in such locations they must have cut gullies and breaches in the hard Carboniferous beds and opened low back country on the weaker Devonians. Some of the existing streams still do so, and these are precisely the ones that are not easily reached by divertors. The Susquehanna in its course outside of the basin has sent out branches that have beheaded all the centripetal streams within reach; where the same river enters the basin, the centripetal streams have been shortened if not completely beheaded. A branch of the Delaware has captured the heads of some of the streams near the eastern end of the basin. Elsewhere, the centripetal streams still exist of good length. The contrast between the persistence of some of the centripetal streams here and their peripheral diversion around Broad Top is a consequence of the difference of altitude of the old lake bottoms in the two cases. It is not to be doubted that we shall become acquainted with many examples of this kind as our intimacy with rivers increases.

41. *Events of the Quaternary cycle.*—The brief quaternary cycle does not offer many examples of the kind that we have considered, and all that are found are of small dimensions. The only capturing stream that need be mentioned has lately been described as a "river pirate;"* but its conquest is only a Schles-

* Science, xiii, 1889, 108.

wig-Holstein affair compared to the Goth- and Hun-like depredations of the greater streams in earlier cycles.

The character of the streams and their valleys as they now exist is strikingly dependent in many ways on the relation of the incipient quaternary cycle to the longer cycles of the past. No lakes occur, exception being made only of the relatively small ponds due to drift obstruction within the glaciated area. Waterfalls are found only at the headwaters of small streams in the plateau district, exception again being made only for certain cases of larger streams that have been thrown from their pre-glacial courses by drift barriers, and which are now in a very immature state on their new lines of flow. The small valleys of this cycle are shallow and narrow, always of a size strictly proportional to the volume of the stream and the hardness of the enclosing rocks, exception being made only in the case of post-glacial gorges whose streams have been displaced from their pre-glacial channels. The terraces that are seen, especially on the streams that flow in or from the glaciated district, are merely a temporary and subordinate complication of the general development of the valleys. In the region that has been here considered, the streams have been seldom much displaced from their pre-glacial channels; but in the northwestern part of the State, where the drift in the valleys seems to be heavier, more serious disturbance of pre-glacial courses is reported. The facts here referred to in regard to lakes, falls, gorges, terraces and displaced streams are to be found in the various volumes of the Second Geological Survey of the State;* in regard to the terraces and the estuarine deflections of the Delaware and Susquehanna, reference should be made also to McGee's studies.†

42. *Doubtful cases.*—It is hardly necessary to state that there are many facts for which no satisfactory explanation is found under the theory of adjustments that we have been considering. Some will certainly include the location of the Susquehanna on the points of the Pocono synclines under this category; all must feel that such a location savors of an antecedent origin. The same is true of the examples of the alignment of water-gaps found on certain streams; for example, the four gaps cut in the

* Especially Carll, Reports I_3, I_4; White, Reports G_5, G_6; Lewis, Report Z.

† Amer. Journ. Science, xxxv, 1888, 367, 448; Seventh Annual Rep. U. S. G. S., 1888, 545.

two pairs of Pocono and Pottsville outcrops at the west end of the Wyoming syncline, and the three gaps where the Little Schuylkill crosses the coal basin at Tamaqua ; the opposite gaps in pairs at Tyrone and Bedford have already been sufficiently explained. The location of the upper North Branch of the Susquehanna is also unrelated to processes of adjustment as far as I can see them, and the great area of plateau drainage that is now possessed by the West Branch is certainly difficult to understand as the result of conquest. The two independent gaps in Tussey's mountain, maintained by the Juniata and its Frankstown branch below Tyrone are curious, especially in view of the apparent diversion of the branch to the main stream on the upper side of Warrior's ridge (Oriskany), just east of Tussey's mountain.

43. *Complicated history of our actual rivers.*—If this theory of the history of our rivers is correct, it follows that any one river as it now exists is of so complicated an origin that its development cannot become a matter of general study and must unhappily remain only a subject for special investigation for some time to come. It was my hope on beginning this essay to find some teachable sequence of facts that would serve to relieve the usual routine of statistical and descriptive geography, but this is not the result that has been attained. The history of the Susquehanna, the Juniata, or the Schuylkill, is too involved with complex changes, if not enshrouded in mystery, to become intelligible to any but advanced students ; only the simplest cases of river development can be introduced into the narrow limits of ordinary instruction. The single course of an ancient stream is now broken into several independent parts ; witness the disjointing and diversion of the original Juniata, which, as I have supposed, once extended from Broad Top lake to the Catawissa basin. Now the upper part of the stream, representing the early Broad Top outlet, is reduced to small volume in Aughwick creek ; the continuation of the stream to Lewistown is first set to one side of its original axial location and is then diverted to another syncline ; the beheaded portion now represented by Middle creek is diverted from its course to the Catawissa basin by the Susquehanna ; perhaps the Catawissa of the present day represents the reversed course of the lower Juniata where it joined the Anthracite. This unserviceably complicated statement is not much simplified if instead of beginning with an original stream and searching out its present disjointed parts, we trace the composition of a single

existing stream from its once independent parts. The Juniata of to-day consists of headwaters acquired from Ohio streams; the lake in which the river once gathered its upper branches is now drained and the lake bottom has become a mountain top; the streams flow around the margin of the lake, not across its basin; a short course towards Lewistown nearly coincides with the original location of the stream, but to confound this with a precise agreement is to lose the true significance of river history; the lower course is the product of diversion at least at two epochs and certainly in several places; and where the river now joins the Susquehanna, it is suspected of having a superimposed course unlike any of the rest of the stream. This is too complicated, even if it should ever be demonstrated to be wholly true, to serve as material for ordinary study; but as long as it has a savor of truth, and as long as we are ignorant of the whole history of our rivers, through which alone their present features can be rightfully understood, we must continue to search after the natural processes of their development as carefully and thoroughly as the biologist searches for the links missing from his scheme of classification.

44. *Provisonal Conclusion.*—It is in view of these doubts and complications that I feel that the history of our rivers is not yet settled; but yet the numerous accordances of actual and deductive locations appear so definite and in some cases so remarkable that they cannot be neglected, as they must be if we should adhere to the antecedent origin of the river courses.

The method adopted on an early page therefore seems to be justified. The provisional system of ancient consequent drainage, illustrated on fig. 21, does appear to be sufficiently related to the streams of to-day to warrant the belief that most of our rivers took their first courses between the primitive folds of our mountains, and that from that distant time to the present the changes they have suffered are due to their own interaction—to their own mutual adjustment more than to any other cause. The Susquehanna, Schuylkill, Lehigh and Delaware are compound, composite and highly complex rivers, of repeated mature adjustment. The middle Susquehanna and its branches and the upper portions of the Schuylkill and Lehigh aré descendants of original Permian rivers consequent on the constructional topography of that time; Newark depression reversed the flow of some of the transverse streams, and the spontaneous changes or adjustments from immature to mature courses in the several cycles of development are so numerous and extensive that, as Löwl truly says, the initial drainage has almost disappeared. The larger westward-flowing streams of the plateau are of earlier, Carboniferous birth, and have suffered little subsequent change beyond a loss of head-waters. The lower courses of the Atlantic rivers are younger, having been much shifted from their Permian or pre-Permian courses by Newark and Cretaceous superimposition, as well as by recent downward deformation of the surface in their existing estuaries. No recognizable remnant of rivers antecedent to the Permian deformation are found in the central part of the State ; and with the exception of parts of the upper Schuylkill and of the Susquehanna near Wilkes-Barre, there are no large survivors of Permian consequent streams in the ordinary meaning of the term "consequent." The shifting of courses in the progress of mature adjustment has had more to do with determining the actual location of our rivers and streams than any other process.

Harvard College, June, 1889.

TOPOGRAPHIC MODELS.

By Cosmos Mindeleff.

Of the many methods by which it has been sought to represent the relief of a country or district, only two have been at all widely used. These methods are, in the order of their development, by hachured and by contoured maps. Both have advantages and both have serious disadvantages. Without entering into the controversy that is even yet raging over the relative merits of the two systems, some slight notice of what each claims to accomplish is necessary.

The representation of relief by hachures is a graphic system, and in the best examples we have is an attempt to show, upon a plane surface, the actual appearance of a given area under given conditions of lighting,—as in the Dufour map of the Alps. Of course certain details that would really disappear if the assumed conditions were actual ones, must be shown upon the map,—so that it is, after all, but a conventional representation. The very best examples are, for this and other reasons, unsatisfactory, and far more so is this the case in the vastly larger class of medium grade and poor work.

The contour system represents relief by a series of lines, each of which is, at every point throughout its length, at a certain stated elevation above sea-level, or some other datum-plane; in other words, each contour line represents what would be the water's edge, if the sea were to rise to that elevation. It possesses the advantage of great clearness, but fails to a large degree in the representation of surface detail; moreover, one must have considerable knowledge of topography, in order to read the map correctly.*

To those who must give first place to the quantity of relief rather than the quality, as, for example, the geologist or the engineer, a contoured map is now considered essential. On the other hand, where quality of relief is the prime consideration and the quantity a secondary one, as, for example, for the use of the army, a hachured map is considered the best. The method

* For specimens of representation of the same subject on different scales, in both the hachure and contour systems, see plate from "Enthoffer's Topographical Atlas."

of hachures may be roughly characterized as a graphic system with a conventional element, and the contour method as a conventional system with a graphic element,—for if the contour interval is small enough a sort of shading is produced which helps considerably the idea of relief.

In addition to these two great systems, with which everyone is more or less familiar, there is another method of representing a country or district,—a method that succeeds where others fail, and which although by no means new, has not received the attention it deserves: this is the representation of a country by a model in relief. Certain striking advantages of models over maps of all kinds are, indeed, so apparent that one almost loses sight of such slight disadvantages as can, of course, be urged against them. In the graphic representation of the surface they are far superior to the hachured map, and they have the further advantage of expressing the relative relief, which the hachured map fails to do, except in a very general way. They have also the advantage of showing actual shadows, exactly as they would be seen in a bird's-eye view of the district, instead of more or less conventional ones, and are, consequently, more easily comprehended by the layman, without becoming any less valuable to the skilled topographer. In short, they combine all the graphic features of a hachured map with all the advantages of the best class of contoured maps, and in addition they show more of the surface detail, upon which so much of the character of the country depends and which is very inadequately expressed by hachures and almost completely ignored in a contoured map of large interval. The contours themselves can be made to appear upon the model very easily and without interfering with other features.

The uses of models are many and various. Within the past few years their usefulness has been much extended, and, now that they are becoming better known, will probably receive a still further extension. To the geologist they are often of great value in working out the structure of complicated districts, for the reason that so many important structural relations can be presented to the eye at a single glance. Similarly, for the graphic presentation of results there is no better method, as the topography, the surface geology, and any number of sections can be shown together and seen in their proper relationship. To the engineer an accurate model is often of the greatest assistance in working out his problems, and it is simply invaluable to explain the details of a plan to anyone who has little or no technical training; for, as has been stated, a model is easily comprehended by anyone, while more or less technical knowledge is required for the proper understanding of even the best maps.

I might go on cataloguing in detail the many uses to which models may be put, but shall now mention only one more—perhaps the most important of all—their use in the education of the young. No method has yet been devised that is capable of giving so clear and accurate a conception of the principles of physical geography as a series of well selected models; models have, indeed, already been used for this purpose, but unfortunately their great cost has prevented their general use in schools. Since, however, the study of geography has been placed upon a new basis and a new life has been infused into it, many men have given their attention to the subject of models, and have experimented with a view to cheapen the cost of reproduction, which has hitherto prevented their wide distribution; and probably this objection will soon be remedied. The ability to read a map correctly,—to obtain from a study of the map a clear conception of the country represented,—is more uncommon than is usually supposed. Some of the recent methods of teaching geography are intended to cultivate this very faculty, but it is doubtful whether there is any better method than that which consists in the study of a series of good models in conjunction with a series of maps, all on the same scale and of the same areas. The value of a series of good models in teaching geology is so apparent that it need only be mentioned. It is often, for reasons stated above, far more valuable even, than field instruction.

For the construction of a good relief map the first requisite is a good contoured map. To this should be added, when possible, a good hachured map, upon which the elevations of the principal points are stated,—if the interval in the contoured map is a large one,—and as much material in the way of photographs and sketches as it is possible to procure. The modeler should, moreover, have some personal acquaintance with the region to be represented, or, failing that, a general knowledge of topographic forms, and at least a clear conception of the general character of the country which he seeks to represent. This is very important, for it is here that many modelers fail: the mechanical portion of the work any ordinarily intelligent person can do. A model may be as accurate as the map from which it is made, every contour may be placed exactly where it belongs, and yet the resulting model may be,—indeed, often is—"flat," expressionless, and unsatisfactory. Every topographer in drawing his map is compelled to generalize more or less, and it is fortunate for the map if this be done in the field instead of in the draughtsman's office. But topographers differ among themselves: there may be, and often is, considerable difference in two maps of the same region made by different men; in other words, the "personal equation" is a larger element in a map than is usually supposed. This being the case, there is something more required in a modeler than the mere transferring of the matter in the map,—giving it three dimensions instead of two: he must supply through his special knowledge of the region (or, failing that through his general knowledge) certain characteristics that do not appear upon the map, and undo, so far as it is necessary, certain generalizations of the topographer and draughtsman. This artistic or technical skill required correctly to represent the *individuality* of a given district is especially important in the modeler; it is more important, perhaps, in small-scale maps of large districts than in large-scale maps of small ones,—for in the latter the generalizing process has not been carried so far, and the smaller interval of the contour lines preserves much of the detail.

The methods by which relief maps are made have always received more attention than would, at first sight, appear to be their proper proportion. It may be due, however, to the difficulty of applying any test to determine the accuracy of the finished model, and perhaps also to the general impression that any one can make a relief map,—and so he can, though of course there will be a wide difference in the value of the results. Some, indeed, have devoted their attention to methods exclusively, letting the result take care of itself,—and the models show it. There is no more reason why a modeler should tie himself down to one method of work, than that a water-colorist, or a chemist, or anyone engaged in technical work, should do so; though in some cases he might be required, as the chemist is, to show his methods as well as his results.

One of the earliest methods, with any pretension to what we may term mechanical control, is that described by the Messrs. Harden in a paper on "The construction of maps in relief," read before the American Institute of Mining Engineers in 1887. The method was published in 1838. Upon a contoured map as a basis cross-section lines are drawn at small and regular intervals, and, if the topography be intricate, corresponding lines at right angles. The sections thus secured are transferred to thin strips of some suitable material, such as cardboard or metal, and cut down to the surface line,—the strips themselves thus forming the cross-sections. These cross-sections are mounted upon a suitable base-board, and the cavities or boxes are then filled up with some easily carved material, such as plaster or wax. The top is then carved down to the form of the country or district,—the necessary guidance being obtained by the upper edges of the strips that form the cross-sections. It will be readily seen that this method is a very crude and laborious one. It necessitates in the first place a good contoured map upon which to draw the sections, but sacrifices much of the advantage thus gained because only a number of points on each contour line are used, instead of the entire line. It is no better, although actually more laborious, than the later method of driving contour pins (whose height above a base-board may be accurately measured,) along the contour lines, and then filling in. A slight modification of the latter method can be used to advantage when no contoured map is available, and when the points whose elevation is known are not numerous enough to permit the construction of one. In this case the only control that can be secured is by means of a number of pins driven into the base-board at those points whose elevation is known. The remainder of the map is then sketched in. This method is perhaps as satisfactory as any, when the material upon the map is scanty. Another method, however, growing out of the same scantiness of material, is in some cases to be preferred, especially for large models. The map is enlarged to the required size, and a tracing of it is mounted upon a frame. Another deep frame, just large enough to contain the mounted tracing, is made, and laid upon a suitable base-board upon which a copy of the map has been mounted. Upon this base-board the model is then commenced, in clay or wax. The low areas are modeled first,—horizontal control being obtained by pricking through the mounted tracing of the map with a needle point, and vertical control by measuring down from a straight edge sliding on the top of the deep frame. This system is rather crude, and only useful where the material upon the map is very scanty, but it gives excellent control.

A method used by Mr. F. H. King in the preparation of his large map of the United States is described by him in a letter to Messrs. Harden, and published by them in the place mentioned. A solid block of plaster is used,—the contoured map being transferred to it—and the plaster is carved down to produce a series of steps like those made by building up the contours. The shoulders are then carved down to produce a continuous surface. This method is one of the best of those that require carving instead of modeling.

Many other methods of producing relief maps might be mentioned, but, as most of them have been used only to make special models, they need not be described. The method that has been more used than any other still remains to be described. It is that which the writer has used almost exclusively, and consists in building up the model and modeling the detail, instead of carving it. It is a maxim of the modeler that the subject should be built up as far as possible, should be produced by adding bits of clay or wax, or other material, and not by carving away what is already on,—by addition and not by subtraction. This may be illustrated by a reference to the methods of the sculptor. The bust, or figure, or whatever the subject may be, is first modeled in clay or wax; from this model a plaster mould is made, and from this mould a plaster cast is taken. This cast is called the original, and the finished production, whether in marble, bronze, or any other hard substance, is simply a copy of this original. No one ever attempts to produce the finished bust or figure directly from the object itself. Even where the artist has for a guide a death mask, the procedure does not change. The bust is first made in clay, and this clay model, as a rule, contains all the detail which subsequently appears in the finished bust. It seems strange, therefore, that the relief map maker should use a method which the sculptor, with infinitely more skill and judgment, is afraid to use; and this on subjects that do not differ as much as might be imagined.

The contour interval to be used depends on the use to which the model is to be put. It is not always necessary to carry into the model all the contour lines upon the map: I may go further and say, that it is not always desirable to do so. The number to be used depends to some extent on the skill of the modeler. As already stated, the contours are only a means of control, and one modeler requires more than another. To build into a model every contour in a contoured map of ten foot interval is a very laborious proceeding, and not worth the time it takes, as in nine out of ten maps of such interval only the fifty-foot or the one hundred-foot curves are definitely fixed, the intermediate lines being merely filled in. This filling in can be done as well, or better, by the modeler.

The question as to the proper amount of exaggeration to be given the vertical scale, as compared with the horizontal, is the question about which has raged most of the controversy connected with relief map making. This controversy has been rather bitter; some of the opponents of vertical exaggeration going to the length of saying that no exaggeration is necessary, and that "he that will distort or exaggerate the scale of anything will lie." On the other hand the great majority of those who have made relief maps insist upon the necessity of more or less exaggeration of the vertical scale—generally more than seems to me necessary, however.

An increase of angle of slope accompanies all vertical exaggeration, and this is apparent even in models in which the vertical element is only very slightly exaggerated. It produces a false effect by diminishing the proportionate width of the valleys, and by making the country seem much more rugged and mountainous than it really is. A secondary effect is to make the region represented look very small—all idea of the extent of the country being lost. This can be illustrated better than described. The King model of the United States is an example of one extreme; it is worthy of note that no examples of the other extreme—too little exaggeration—are known.

In small-scale models of large districts some exaggeration of the vertical scale is necessary in order to make the relief apparent, but the amount of this exaggeration is often increased much beyond what is essential. The proportion of scales must depend to a large extent on the character of the country represented, and on the purposes for which the model is made. It has been suggested by a writer, quoted by the Messrs. Harden, that the following exaggeration would afford a pleasing relief: "For a map, scale 6 inches to 1 mile: if mountainous, 1:3; if only hilly, 1:2; if gently undulating, 2:3. For smaller scales, except for very rugged tracts, the exaggeration should be correspondingly increased. For a tract consisting wholly of mountains no exaggeration is necessary." I know of no country of such a character that its relief, in all its detail, cannot be shown upon a scale of 6 inches to 1 mile without any exaggeration at all.

It seems to me that the absolute and not the relative amount of relief is the desideratum, and I have always used this as my guiding principle. For small scale models I have found half an inch of relief ample. It may be worth while to state that in a model of the United States made for the Messrs. Butler, of Philadelphia, the horizontal scale was 77 miles to 1 inch, the vertical scale 40,000 feet to 1 inch, and the proportion of scales as 1 to 10. This proportion could have been brought down as low as 1:6 with advantage. One-fortieth of an inch to a thousand feet seems a very small vertical scale, but it sufficed to show all the important features of the relief. It should be stated, moreover, that the model in question was very hurriedly made—in fact, was hardly more than a sketch-model—and that more care and more minute work would have brought out many details that do not now appear. This amount of care was not considered necessary in this instance, as the model was made to be photographed and published as a photo-engraving, and was to suffer an enormous reduction—coming down to five by seven inches.*

It has been frequently urged by the advocates of large exaggeration that the details of a country cannot be shown unless the vertical scale is exaggerated; that hills 200, 300, or even 500 feet high—depending of course upon the scale—flatten out or disappear entirely. This seems plausible, but the advantanges of great exaggeration are more apparent than real. Its effect upon the model has already been mentioned; it should be added that, with the proper amount of care in finishing the model, exceedingly small relief can be so brought out as to be readily seen. With ordinary care, one-fortieth of an inch can be easily shown, and with great care and skill certainly one-eightieth and probably one-hundredth of an inch. Another plausible argument that has been advanced in favor of vertical exaggeration as a principle, is well stated by Mr. A. E. Lehman, of the Pennsylvania Geological Survey, in a paper on "Topographical Models," read before the American Institute of Mining Engineers in 1885. "A perfectly natural expression is of course desired; and to cause this the features of the topography should be distorted and exaggerated in vertical scale just enough to produce the same effect on the beholder or student of the district of country exhibited

* See plate from "Butler's Complete Geography."

as his idea of it would be if he were on the real ground itself. Care should be taken, however, not to make the scales so disproportionate as to do violence to mental impressions. Often, indeed, prominent or important features, when they will bear it, may be still more effectively shown by additional exaggeration in the vertical scale." The fallacy of this argument is obvious. It assumes that the object of a model is to show the country as it appears to one passing through it, and not as it really is—and there is often a very wide difference between the two. The impression derived from passing through a country is, if I may use the term, a very large-scale impression, as any one who has tried it can certify ; it is certainly a mistake to attempt to reproduce this impression in a small-scale model, with the help of vertical exaggeration. Even if the principle were a good one, its application would be very limited. It could only be used in large-scale models ; to apply it to a model of a large area—the United States, for example—is obviously absurd.

The method referred to as being now generally in use may be briefly described as follows : requisites, a good contoured map ; a hachured map in addition, if possible ; a clear conception on the part of the modeler of the country to be represented ; and a fair amount of skill. Materials : a base-board of wood or other suitable material ; card-board or wood of the thickness required by the contour interval and the scale ; and modeling wax or clay. Procedure : reproduce the contours in the wood or other material ; mount these upon the base-board in their proper relationship ; then fill in the intervening spaces, and the space above the topmost contour, with the modeling material.

In a series of models of the Grand Divisions of the earth, made about a year and a half ago, the contours of card-board were made as follows : the map was photographed up to the required scale, and as many prints were made as there were contour intervals to be represented—in a model of the United States of 1,000 feet contour interval there were fourteen prints. Thirteen of these were mounted upon card-board of the exact thickness required by the vertical scale, and one upon the base-board. All large paper companies use a micrometer gauge, and card-board can easily be obtained of the exact thickness required—even to less than the thousandth part of an inch. The lowest contour was then sawed out upon a scroll saw, and placed upon the corresponding line of the map mounted upon the base-board. This process was repeated with each of the succeeding contours until all were placed and glued into their proper positions. At this stage the model presents the relief in a series of steps, each step representing a rise corresponding to the contour interval. The disadvantages of the method lie in the fact that unless the greatest care is exercised in making the photographic prints there will be considerable distortion, owing to the stretching of the paper in different directions, and consequently much trouble in fitting the contours. If care be exercised in having the grain of the paper run in the same direction in all the prints, trouble in fitting the contours will be much reduced, but the distortion in one direction will remain. In our experience this distortion amounts to about two per cent.; in other words, a model that should be fifty inches long will in reality be fifty-one inches ; but, as this error is distributed over the whole fifty inches, it is not too great for an ordinary model. If greater accuracy be required, it can be secured by transferring the contours to the card-board by means of tracing or transfer paper. The great advantage of the photographic method lies in the fact that when the model has been built up, with all the contours in position, it presents a copy of the map itself, with all the details, drainage, etc., in position, instead of blank intervals between the contours. Such details and drainage are a great help in the subsequent modeling.

The next step in the process is to fill in with clay or wax the intervals between the contours. I have always found wax more convenient than clay for this purpose as, unless the surface coating is a thick one, the clay is difficult to keep moist. To obviate this difficulty, some modelers have used clay mixed with glycerine instead of water ; this, of course, does not become dry, but the material is, at its best, unsatisfactory. The filling-in process is the most important one in relief map making, for it is here that the modeler must show his knowledge of, and feeling for, topographic forms. Some models seem to have been constructed with the idea that when the contours have been accurately placed the work of the modeller is practically done. This is a great mistake. The card-board contours are only a means of control, occupying somewhat the same relation to the relief map that a core or base of bricks, or a frame of wood, does to other constructions as, for example, an architectural ornament or a bust. It is sometimes necessary to cut away the contour card ; for, as has been already explained, a map is more or less generalized, and a contour is frequently carried across a ravine, instead of following it up, as it wonld do if the map were on a larger scale. Such generalizing is of course perfectly proper in a map, but, with the same scale, we expect more detail in a model. The modeler must have judgment enough and skill enough to read between the lines, and to undo the generalizing of the topographer and draughtsman, thus supplying the material omitted from the map. This can be done without materially affecting the accuracy of the model, considered even as a copy of the contoured map.

The contours of card board or other material are, let me repeat, only a means of control. The perfect modeler—a variety, by the way, yet to be evolved—would be able to make an accurate relief map without them, in the same way that other subjects are made ; as, for example, a flower panel, an architectural ornament, or any other subject in low relief, where the object sought is artistic effect and great accuracy is not a desideratum. It is the converse of this idea that has produced the numerous models that one sees ; accurate enough, perhaps, but wholly expressionless and absolutely without feeling. This is the great fault of nearly all models made by building up the contours in wood and then carving down the shoulders. It is then necessary to sandpaper them, and what little character they might otherwise have had is completely obliterated by the sand-paper. Such models almost invariably *look* wooden. Let the modeler, then, have a clear conception of his subject and not depend wholly on the contours, and let him work out that conception in his model, "controlled" and helped by the contours, but not bound by them ; the resulting model will thus be far more satisfactory and a far better representation of his subject, in other words, it will be more life-like—more nearly true to nature.

The model, provided it be not of clay, is sometimes used in the state in which it is left when finished. It is much more common, however, to make a plaster mould, and from this a plaster cast. For this purpose a moulder is usually called in ; but moulders as a rule are ignorant men, accustomed to one line of work only, and the result is not always satisfactory. It is much better for the modeler himself to do this work, though to obtain good results from plaster it is necessary to know the material thoroughly, and this knowledge comes only from experience. The mould is generally made quite heavy, in order to stand the subsequent hard treatment that it may receive, and should be retouched and thoroughly dried before being prepared for the cast. The method used by some modelers of placing a frame about the model and pouring in the plaster, filling the frame to the top, is a crude and very wasteful one and not at all to be recommended. In a model of large size—say seven or eight feet square—it would require a derrick to move the mould. It is wholly unnecessary, as, with a small amount of care, a good mould can be made not more than an inch thick, or, at most, an inch and a half. The drying of the mould before use can sometimes be dispensed with, but is always desirable.

Nearly all American moulders (as distinguished from French and Italian ones) varnish the mould, and thus lose some of the finest detail and sharpness. This is unnecessary. The mould can be easily prepared with a solution of soap so as to leave nothing on the surface but a very thin coating of oil, which is taken up and replaced by the plaster of the cast. Of course, if the model has been sand-papered, no fine work in moulding or casting is necessary, as there is nothing to save. If the subject is a very intricate one, with "undercuts" (as they are called), it is customary to make a waste mould; as this is very seldom necessary in relief map work, however, the process need not be described.

To make the cast it is only necessary to repeat the processes used in making the mould. With great care and some skill a cast can be produced but little inferior in point of sharpness and detail to the original model. It is customary to make the cast very thick, and, consequently, very heavy; this is unnecessary. In our work we seldom make a cast thicker than one inch, and yet are never troubled with changes in the model after it is finished. Even in a very large cast (now in the National Museum), weighing nearly 1,500 pounds and presenting a surface of over 160 square feet, the average thickness is less than one inch, although it required over five barrels of plaster to make it. The cast, after being thoroughly dried, should be finished—all its imperfections being carefully repaired. The surface, however, should be touched as little as possible, as the slight roughness of surface that comes from the original model, through the mould, is removed by any tooling. This roughness adds much to the effect of the model; in fact, where the scale is large enough, it is sometimes desirable to emphasize it.

The proper way to paint a model is a matter that must rest principally upon the judgment of the modeler, depending to some extent, also, on the use to which the model is to be put. The plain cast is sometimes used, drainage, lettering, etc., being put directly upon it. This has the advantage of preserving all the detail that comes from the mould, but it has also the disadvantage of a surface easily soiled and impossible to clean. If the model is to be photographed, the surface should be nearly white—in our practice we use a small amount of yellow with the white. This yellow is hardly appreciable by the eye, but its effect upon the photographic negative is quite marked. Yellow becomes grey in a photograph, and, in a photograph of a model colored as described, a grey tint is given to the whole surface. The high lights are not pure white, and there is no harsh contrast between light and shade. There is another point of great importance in photographing models: the surface should have a dead finish—that is, should have no gloss, or, at most, should have only what is known among painters as an egg-shell gloss. It is almost impossible satisfactorily to photograph a model that has a shiny surface. Any portion of a model that it is desired to separate from the rest should be painted a different color—the water, for example, should be painted a light blue; not a blue composed of indigo, however, or any of the grey blues, as these produce in the photograph a dead grey, and are not pleasant to the eye. The most satisfactory color that we have used is a mixture of cobalt—the purest of the blues—with Antwerp blue—which is quite green—and white. This gives a color that is pleasant to the eye, has the retreating quality to perfection, and photographs well.

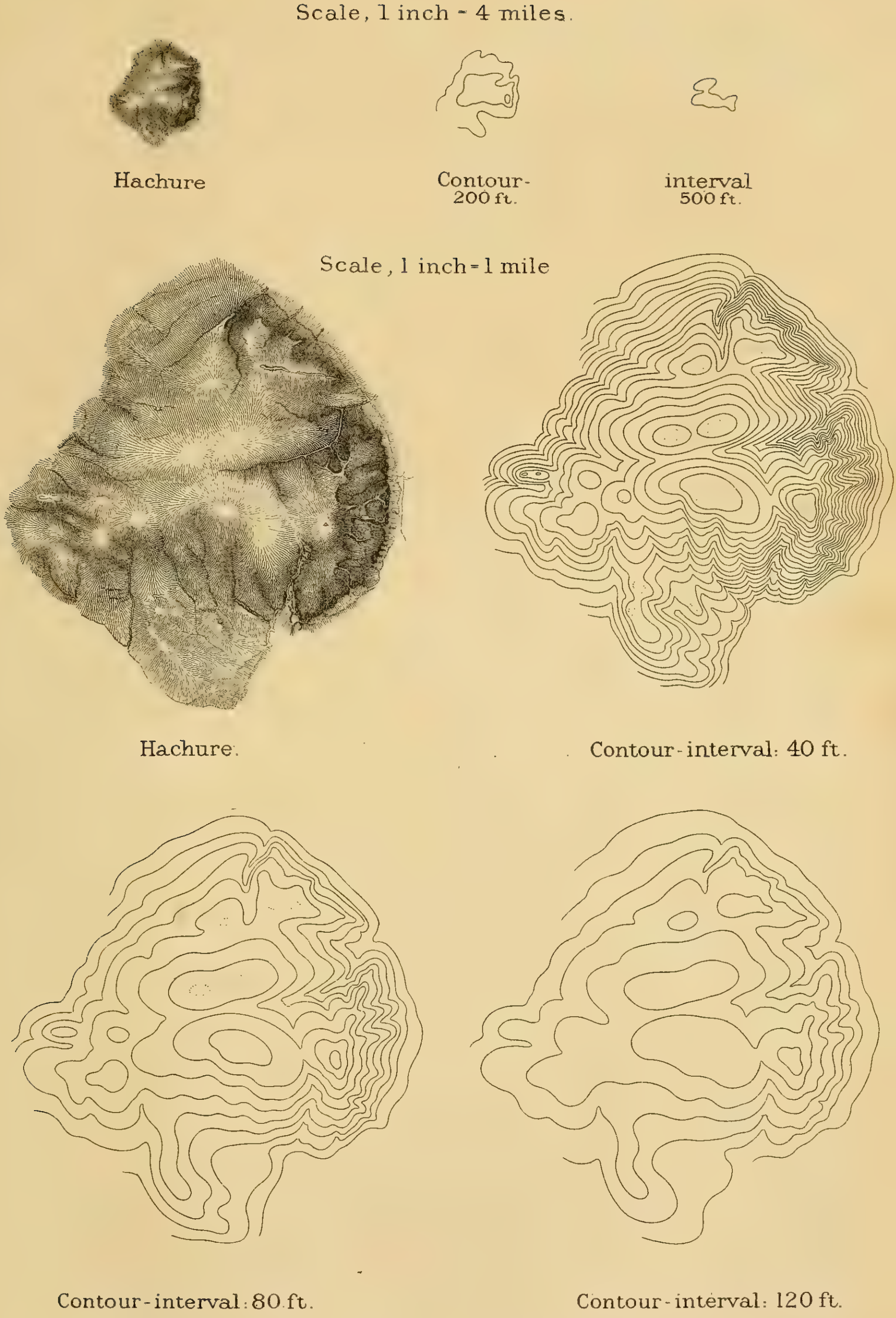
Models intended for exhibition as such should be painted realistically. There is room here for an immense improvement in the usual practice, which is to paint the model either in some conventional scheme of light and shade, or else to put a single flat tint upon it. If the model is to be colored conventionally it is, in my opinion, much better to use a flat tint, light in tone, and with a dead surface. The use of a variety of colors upon the face of a model interferes materially with the relief, especially if the relief is finely modeled. For this reason models colored to indicate geologic formations should always be accompanied by duplicates representing topography only, colored realistically, if possible, and without lettering. Well-defined lines other than those pertaining to the model itself, such, for example, as those used to define the boundaries of geologic formations, should not be allowed upon a model when it is desired to bring out all the relief. The lettering on such models should be kept down as small as possible, or wholly dispensed with. The latter is much the better method.

The cheap reproduction of models is the most important problem connected with the art, and the one that is attracting most attention among those engaged in it; as, until models can be reproduced cheaply, they will never have any wide distribution and there will be far less incentive to the modeler. Various materials have been suggested and experimented on, but nine-tenths of the models that are made to-day are made of plaster of Paris. Although this material was the first to be used for this purpose, it has not yet been superseded. A plaster cast is heavy, expensive and easily injured; but plaster gives an accurate copy of the original, retains permanently the form given it, and is easily finished and repaired. The weight is an obstacle that can be easily overcome. By the incorporation in the plaster of fine tow, or of bagging or netting of various kinds, the cast can be made very light and at the same time strong, but the expense is increased rather than diminished by this method. Models made in this way, however, have the advantage that when broken the pieces do not fall out, they are, however, fully as liable to surface injury as the other kind. The large cast in the National Museum, before referred to, was made in this way. It weighed nearly 2,000 pounds when boxed—not an easy thing to handle—but it stood shipment to New Orleans and back without suffering any material injury. This would hardly have been possible had the cast been made from plaster alone.

Paper seems, at first sight, to be the material best adapted for the reproduction of models; but no one has succeeded well enough with it to bring it into use. Like nearly all those who have given this subject attention, I have experimented with paper, but the only positive result has been a loss of a large part of the confidence that I once had in the suitability of the material. Paper has been used extensively for large scale models of pueblos, ruins, etc., but I have never obtained a satisfactory result with subjects in low relief and fine detail. A paper cast may look well when first made, but it absorbs moisture from the atmosphere, and contracts and expands with the weather. The contraction is apt to flatten out the model and the expansion to make it buckle up.

Casts of models have been made in iron; but this, while suitable perhaps for models of mounds and subjects of like character, would hardly be applicable to small scale models with fine detail; such casts require too much surface finishing. The material known as Lincrusta-Walton seems to me to be the ideal material for this purpose. It is tougher than rubber, will take the finest detail, and its surface can be treated in any way desired. Unfortunately the manufacture of models in this material would require expensive machinery, and is outside the scope of a modeling room. Should it ever become commercially advantageous, however, casts of a model of ordinary size, in every way equal to the original, can be turned out in this material at a very small cost.

It remains to speak of the reproduction of models by process-engravings—a method that will probably receive much more attention in the future than it has in the past. It is perhaps along this line that the cheap reproduction of models will develop; but the subject is too large a one to be adequately treated here, and must be postponed until some future occasion.



HACHURED AND CONTOURED MAPS

REPRESENTATION OF A HILL ACCORDING TO THE TWO SYSTEMS AND ON DIFFERENT SCALES.

From Supplement to Enthoffer's Topographical Atlas by permission of Mr. Enthoffer.

FROM BUTLER'S COMPLETE GEOGRAPHY.

NATIONAL GEOGRAPHIC SOCIETY.

ABSTRACT OF MINUTES.

October 5, 1888, *Ninth Meeting.*

A paper was read entitled, "Topographic Models," by Mr. Cosmos Mindeleff. Published in the "National Geographic Magazine," Vol. I, No. 3.

October 19, 1888, *Tenth Meeting.*

The attendance being very small, no paper was read.

November 2, 1888, *Eleventh Meeting.*

The paper of the evening was entitled, "Surveys, their Kinds and Purposes," by Mr. Marcus Baker. The paper was discussed by Messrs. Ogden, Goodfellow, Gannett and Baker. Published in "Science," Vol. XII, No. 304.

November 16, 1888, *Twelfth Meeting.*

A paper was read by Mr. Henry Gannett, giving certain "Physical Statistics Relating to Massachusetts," derived from the map of that State recently prepared by the United States Geological Survey. A discussion followed which was participated in by Messrs. Baker, Kenaston, Fernow, Weed, and the author. A second paper entitled, "Something about Tornadoes," was read by Lieut. J. P. Finley, U. S. Signal Corps.

November 30, 1888, *Thirteenth Meeting.*

The annual reports of vice-Presidents Herbert G. Ogden and Gen. A. W. Greely were delivered. Published in the "National Geographic Magazine," Vol. I, No. 2.

December 20, 1888, *Fourteenth Meeting.*

Held in the Law Lecture Room of the Columbian University. The President delivered his Annual Address, entitled, "Africa." Published in the "National Geographic Magazine," Vol. I, No. 2.

December 28, 1888, *Fifteenth Meeting.*

The Society met in the Society Hall of the Cosmos Club, President Hubbard in the chair. Owing to the absence from the city of the Secretaries, Mr. O. H. Tittmann was requested to act as Secretary of the meeting. The minutes of the first and fourteenth meetings were read and approved. The report of the Secretaries was read, in their absence, by the temporary Secretary, and was approved. The Treasurer's report, showing a balance on hand of $626.70, was read and approved, as was also that of the auditing committee.

The President announced that vacancies caused by the resignation of two of the managers, Messrs. W. D. Johnson and Henry Mitchell, had been filled by the Board on the 15th of November, by the election of Messrs. O. H. Tittmann and C. A. Kenaston; and that a vacancy caused by the resignation of Vice-President John R. Bartlett, had been filled by the election of Lieut. George L. Dyer, on November 30th.

The Society then proceeded to the election of officers, with following result:

President—GARDINER G. HUBBARD.

Vice-Presidents—HERBERT G. OGDEN, [land]; GEORGE L. DYER, [sea]; A. W. GREELY, [air]; C. HART MERRIAM, [life]; A. H. THOMPSON, [art];

Treasurer—CHARLES J. BELL.

Recording Secretary—HENRY GANNETT.

Corresponding Secretary—GEORGE KENNAN.

Managers—CLEVELAND ABBE, MARCUS BAKER, ROGERS BIRNIE, JR., G. BROWNE GOODE, W. B. POWELL, J. C. WELLING, C. A. KENASTON, O. H. TITTMANN.

January 11, 1889, *Sixteenth Meeting.*

The paper of the evening was entitled, "The Great Plains of Canada," and was presented by Professor C. A. Kenaston, of Howard University.

January 25, 1889, *Seventeenth Meeting.*

The paper of the evening was entitled, "Irrigation in California," by Mr. William Hammond Hall, State Engineer of California. To be published in the "National Geographic Magazine," Vol. I, No. 4.

February 8, 1889, *Eighteenth Meeting.*

The following papers were read by Prof. W. M. Davis, of Harvard University: "Topographic Models," and "Certain Peculiarities of the Rivers of Pennsylvania." Published in the "National Geographic Magazine," Vol. I, No. 3.

February 22, 1889, *Nineteenth Meeting.*

The paper of the evening was entitled, "Round about Asheville, N. C.," by Mr. Bailey Willis. The paper was illustrated by charcoal sketches and lantern slides. Discussion followed, which was participated in by Messrs. Baker, Merriam and McGee. To be published in the "National Geographic Magazine," Vol. I, No. 4.

March 8, 1889, *Twentieth Meeting.*

The following amendments to the By-Laws were adopted.

[For Article VI substitute the following]:

ARTICLE VI.

MEETINGS.

"Regular meetings of the Society shall be held on alternate Fridays, from November until May, and excepting the annual meeting, they shall be devoted to communications. The Board of Managers shall, however, have power to postpone or omit meetings, when deemed desirable. Special meetings may be called by the President.

"The annual meeting for the election of officers shall be the last regular meeting in December.

"The meeting preceding the annual meeting shall be devoted to the President's annual address.

"The reports of the retiring Vice-Presidents shall be presented at the meetings in January.

"A quorum for the transaction of business shall consist of twenty-five active members."

In Article V, the following paragraph was introduced immediately after the first paragraph of the article:

"The dues of members elected in November and December shall be credited to the succeeding year."

The following papers were then presented: "A Trip to Panama and Darien," by Mr. R. U. Goode, and "Survey of Mason and Dixon's Line," by Mr. Mark B. Kerr.

A Trip to Panama and Darien, to be published in the "National Geographic Magazine," Vol. I, No. 4.

March 22, 1889, *Twenty-first Meeting.*

The paper of the evening was entitled, "Recent Events in the U. S. of Columbia," by Mr. W. E. Curtis. The discussion which followed was participated in by Messrs. Baker, Gannett, and others.

April 5, 1889, *Twenty-second Meeting.*

The paper of the evening was entitled, "House Life in Mexico," by Mr. A. B. Johnson.

April 19, 1889, *Twenty-third Meeting.*

This meeting was devoted to papers upon the Samoan Islands. The following programme was presented:

"Samoa; the General Geography and Hydrography of the Islands and Adjacent Seas," by Mr. Everett Hayden.

"Climate," by Prof. Cleveland Abbe.

"Narrative of a Cruise Among the Islands," by Capt. R. W. Meade, U. S. N.

"The Home Life of the Samoans and the Botany of the Islands," by Mr. W. E. Safford, U. S. N.

May 3, 1889, *Twenty-fourth Meeting.*

The paper of the evening was entitled, "Across Nicaragua with Transit and Machéte," by Mr. R. E. Peary, U. S. N. To be published in the "National Geographic Magazine," Vol. I, No. 4.

May 17, 1889, *Twenty-fifth Meeting.*

The paper of the evening was entitled, "The Krakatoa Eruption," by Dr. A. Graham Bell. The paper was discussed by Captain C. E. Dutton.

(*Translated by Mr. R. L. Lerch.*)

INTERNATIONAL LITERARY CONTEST

To be held at Madrid, Spain, under the auspices of the Commission in charge of the celebration of the Fourth Centennial Anniversary of the Discovery of America.

PROGRAM.

The work for which a prize is offered is to be a prose essay, a true historic picture giving a just estimate of the grandeur of the occasion to be celebrated.

So much has been written on this subject since the opening of the XVIth century that it would seem difficult to say anything new and good. Perhaps the details, perhaps the circumstances in the life and acts of Columbus are worthy of no little research; but already the Royal Academy of History is engaged in the erudite and diligent task of bringing together and publishing the un-edited or little known papers bearing on this question.

The book required by this contest must be of a different nature: it must be comprehensive and synoptic, and must be sufficiently concise without being either obscure or dry.

Although there is an abundance of histories of America, of voyages and discoveries, of geographic science, and of the establishment of Europeans in remote regions of the earth, there is no book that sets forth as it can be done the combined efforts of the nations of the Iberian peninsula, who, since the commencement of the XVth century, have, with a fixity of purpose and marvelous tenacity, in almost a single century of silent efforts brought about the exploration of vast continents and islands, traversed seas never before cut by Christian prows, and in emulous strife obtained almost a complete knowledge of the planet on which we live.

There is a growing interest and manifest unity in all those more important events; not to mention the circumstantial evidence borne by the charts of 1375 and the semi-fabulous voyages, such as that of Doria y Vivaldi and others less apocryphal though isolated and barren of results, like that of Ferrer, begun in 1434, when Gil Eannes doubled Cape Bojador, discovered Guinea, and dispelled the terror inspired by the unknown ocean, and ended in 1522 with Elcano's arrival at Sanlucar after circumnavigating the globe.

In all this activity very little occurs by chance. The progressive series of geographic discoveries, due to persistent premeditation and not to accident, was inaugurated at Sagres by the Infante D. Enrique and his illustrious pilot Jaime de Mallorca.

Well might Pedro Nuñes exclaim that from that time forth until the form and size of the terraqueous globe were thoroughly known, the most to be obtained would not be firmly established, "unless our mariners sailed away better instructed and provided with better instruments and rules of Astronomy and Geography than the things with which cosmographers supplied them."

The culmination in the progress of that beautiful history falls on the 12th of October, 1492, when Columbus was the first European to set foot upon the intertropical shores of the New World. But this act, considered apart from its intrinsic value, as purely the individual inspiration of a mariner and the generous enthusiasm of a patron Queen, derives a higher value when regarded as part of a summation of efforts, a grand development of an idea, a purpose to explore and know the whole globe, to spread the name and the law of Christ together with the civilization of Europe, and to reap a harvest of gold, spices, and all the riches of which costly samples and exaggerated reports were furnished by the traffic of the Venetians, Genoese and Catalonians, who in turn got them from Mussulmans.

Doubtless the moving cause, whose gorgeous banner so many men of our peninsula followed, was clothed in great sentiments, good or bad; their hearts were filled with religious fervor, thirst for glory, ambition, Christian love, cupidity, curiosity, and violent dissatisfaction (even during the Renaissance), to seek and undergo real adventures that should surpass the vain, fruitless, and fanciful adventures of chivalry; and to make voyages and conquests eclipsing those of the Greeks and Romans, many of which, recorded in classic histories and fables, were now disinterred by the learned.

What must be described is the complete picture in all its sumptuousness so that its magnificent meaning may stand out distinctly, without which the conviction would be lacking that the studies, voyages, and happy audacity of Bartolomé Diaz, Gama, Alburquerque, Cabral, Balboa, Magallanes, Cortes, Pizarro, Orellana, and a host of others, do not dim the glory of the hero whose centennary is to be celebrated, even though it heighten and add greater luster to the work of civilization begun by Portugal. . . .

The book here vaguely outlined must also contain a compendious introduction, notices of voyages, ideas, and geographic progress up to the date of D. Enrique's establishment at Sagres, and an epilogue or conclusion of greater extent, in which are examined and weighed the changes and progress that our subject has made, collectively, in the civilization of the world—in the commerce, economics and politics of the peoples, in regard to the broad field opened to the intelligent activity of Europe, over which it could spread and dominate; the abundance of data, sunken hopes, and more secure basis lent to the studious and wise for the extension of our knowledge of Nature, the unraveling of her laws, and penetration of her mysteries.

The vast, elevated argument of the book requires it be a finished work of art, not in fullness and richness of diction, but in plan and order, in sobriety and unity of style, whose nobility and beauty must lie in simplicity of phrase, correctness of judgment and richness of thought.

There may enter into this contest any unpublished work written to this end in Spanish, Portuguese, English, German, French or Italian.

The tribunal that is to award the prize will be composed of two members of the R. Acad. of History, and one member from each of the Spanish R. Academies of Moral Sciences and Politics, and Exact and Natural Sciences—all to be chosen by the Academies themselves.

Furthermore, there will be included in the tribunal the diplomatic representative of every power whose subject or subjects wish to enter the contest, which is to be done through said representative or some person duly appointed to act in his place.

The tribunal will elect its presiding officer and will decide on the best works by an absolute majority of all the jurors who take part in the vote.

Each work submitted in this contest must be neatly copied, in legible writing, on good paper, without the author's name but with a quotation to identify him afterwards.

Each author will inclose a separate folded sheet on whose exterior is written the quotation he has chosen and the opening sentence of his work ; within, he will write his name and residence.

The folded sheets corresponding to the works that did not get a prize will be burnt publicly without being opened.

Though it is difficult to set a limit as to size, the works should not have more reading matter than is contained in two volumes of the shape and size of the complete works of Cervantes issued by Rivadeneyra in 1863–4.

If the plan or purpose of any of the works require it, there may be added another volume of documents, maps, or other illustrations.

As it will take time to examine and judge the works, they should be sent to the Secretary of the R. Acad. of Hist. prior to January 1, 1892.

There will be first prize of 30,000 pesetas ($5,790) and a second of 15,000 pesetas ($2,895).

Besides this, each of the two successful authors will receive 500 copies of the printed edition of his work.

It rests with the Centennial Commission to determine the number of copies in the edition of each of the two prize works, and what disposition is to be made of the copies that are not given to the authors.

These (the authors) keep the right to re-print and to sell their works, and to translate them into other tongues.

The Commission, however, will have the right, if either or both prize works are in a foreign tongue, to have them translated and published in Castilian.

The Commission affix their seal to the preceding directions for the information of the public and government of those persons who desire to participate in the contest.

Madrid, June 19, 1889.

The Vice President, Duke of Veragua.
Secretaries, Juan Valera, Juan F. Riaño.

Vol. I. No. 4.

THE

NATIONAL GEOGRAPHIC MAGAZINE.

PUBLISHED BY THE

NATIONAL GEOGRAPHIC SOCIETY.

WASHINGTON, D. C.

Price 50 cents.

CONTENTS.

OCTOBER, 1889.

PRESS OF TUTTLE, MOREHOUSE & TAYLOR, NEW HAVEN, CONN.

THE

NATIONAL GEOGRAPHIC MAGAZINE.

Vol. I. 1889. No. 4.

IRRIGATION IN CALIFORNIA.

By Wm. Hammond Hall.

Mr. President and Gentlemen of the Society:

When I was invited to address this society I had no material at hand on the subject. I have come to the east without any notes or memoranda whatever, from which to prepare a lecture or address, no statistical data which would make a paper valuable, no notes of characteristic facts to render an address interesting, and no time to write anything to guide me in any way to a proper treatment of the subject. Some of your members have thought that I have written something worthy of being read, and hence this invitation to address you. But, even if they are right, people who can write cannot always talk, so if I fail in this address, I shall hope, on the basis of their opinion, that you will find in the reports I have written something worthy of reading. The subject has been announced as the "Problems of Irrigation in the United States." I should like very much to speak broadly on that subject, but I am unable to do so, for the reasons I have given, and shall have to speak rather of irrigation in California, trusting that something which is said, may, perchance, be valuable in relation to the subject at large. Irrigation in the far west, generally, is attracting a vast deal of attention. This is particularly the case on the Pacific Coast—the field with which

I am specially acquainted. I apprehend that although many gentlemen present have a far-reaching and definite appreciation of the subject at large, many others do not appreciate the value and importance of irrigation. In the arid parts of California (for we do not admit that California is as a whole arid) it is a vital matter. There it is a question of life, for the people. Not more than one-sixth of the tillable area in the State can sustain a really dense population, without irrigation ; two thirds of it will not sustain even a moderate population, without irrigation ; while one third will not sustain even a sparse population, without such artificial watering. Think well over these facts. They are very significant. I doubt whether they are generally appreciated in California itself.

I have no doubt many persons are familiar with the geography of the State, but, doubtless, some are not. California has a coast line of 800 miles and a width of from 140 to 240 miles. It is traversed almost throughout its length by a great mountain chain extending along near the eastern boundary, which is called the Sierra Nevada, and by a lesser range, more broken and less unified, running parallel to the coast, called the Coast Range, the southern extension of which, after joining the Sierra Nevada, is called the Sierra Madre, and at the further extremity, the San Jacinto and San Diego mountains. Within the interior of the State, looked down upon by the Sierra Nevada on the east, and closed in by the Coast Range on the west, is the great interior basin—the valley of the San Joaquin and Sacramento rivers—forming a plain 450 miles long, with an average width of from 40 to 60 miles. Outside of the Sierra Madre in the southern part of the State, and within the Coast Range, is another interior valley, nearly 100 miles in length and from 20 to 30 miles in width, and outside of the Coast Range, and lying next to the ocean, is a plain whose length is from 60 to 70 miles, and width 15 to 20 miles. These three areas—the great interior valley, the southern interior valley, and the coast plain of the south—are the principal irrigation regions of the State. Numbers of smaller areas, as those in San Diego county, come in as irrigation regions of less importance, and the scattering valleys along the Coast Range farther north, as the Salinas, etc., will come forward in the future as important irrigable districts of the State. Still further north, in the interior, there are the great plains of Lassen and Mono counties, and some scattering valleys in Shasta county, where irrigation is also practiced or is being introduced, and these are on a par with the districts of San Diego county, in the matter of rank as irrigation regions. East of the Sierra Nevada, and at their base, lies the Owen's river country, an area suitable for irrigation, where irrigation is necessary and where it is being introduced. Upon the great Mojave desert and the Colorado desert, there is at present no irrigation. The water supply is very scanty. This is an irrigation region of the future, but it is not regarded by Californians as a practicable one at present.

With this general idea of the State, we will now look at the rainfall and water supply. The State contains 157,440 square miles of territory, of which 17,747 drain into the ocean north of the Golden Gate, 21,665 drain into the ocean south of the Golden Gate, 55,942 drain into the interior basins, and 62,086 drain out at the Golden Gate. Of this territory which drains out by the Golden Gate, 26,187 square miles comprise the Sacramento valley, 31,895 square miles the San Joaquin valley, and 4,004 the country draining directly to the bays, making the 62,086 given above as the whole area.

The necessity for irrigation in California, and the relative necessity in different parts of the State, are shown by the distribution of rainfall. The San Joaquin valley has an average of less than 10 inches of rainfall, the Sacramento has an average of between 10 and 20 inches. The great deserts of the Mojave and Colorado have an average of less than 10 inches, and in certain localities only 3 to 6 inches. The Salinas valley, a small portion of the coast above Los Angeles, and a portion of the interior valley of the south, have also an average of less than 10 inches.

So, we may say, that the great irrigation regions of California have average amounts of rainfall varying from about 6 up to 20, but generally less than 10 inches. This rain is distributed in four or five months of each year, with some slight showers in one or two months other than these; the remainder of the year being absolutely dry, with no rainfall whatever. Hence, you will see at once, the necessity for the artificial application of water in California. In the older countries of Europe, where irrigation has been practiced for centuries, for instance, in Spain, where water is used more extensively than in California, the annual mean rainfall ranges between 10 and 25 inches. In the irrigation regions of France, the mean rainfall ranges from 10 to 40 inches; in the irrigation regions of Italy, the rainfall is between

20 and 35 inches—for instance, in the valley of the Po, the classic land of irrigation, the annual precipitation is from 25 to 35 inches. There are none of these European irrigation regions where the rainfall is less than 10, and generally it is over 20 inches. But you will see that the most of the Californian irrigation regions have less than 15 inches, some less than 10, and the greatest rainfall of any large irrigable region in California is 18 inches, or, exceptionally, for smaller regions, 25 inches ; while in Europe, the maxima are from 25 to 40 inches in countries where irrigation has long been practiced. It follows, then, that there is no place in Europe where it is so much needed as over a large part of California. Another reason why the necessity is felt in our Pacific Coast State, is found in the character of our soils ; and not alone the surface soils, but the base of the soil—the deep subsoils. We have soils exceptionally deep ; soils which extend below the surface to 50 feet, underlaid by loose sand and open gravels, so that the rainfall of winter is lost in them. The annual rain seldom runs from the surface. It follows that these lands are generally barren of vegetation without the artificial application of water.

Considering now the sources of water-supply : we have in the southern part of the State many streams which flow only for a few weeks after rainfall, and other streams which run two or three months after the rainy season. But there is not a stream in all California south of the Sierra Madre (except the Colorado, which has it sources of supply outside of the State) which flows during the summer with a greater volume than about 70 to 80 cubic feet per second—a stream 15 feet in width, 2 feet deep, and flowing at the rate of 2½ to 3 feet per second—a little stream that, in the eastern part of the continent, would be thought insignificant. The largest stream for six months in the year, in all southern California, is the Los Angeles river. The Santa Aña river, the next largest, flows from two sevenths to one third as much ; the San Gabriel, the next largest, has perhaps two thirds or three fourths as much as the Santa Aña ; and so, a stream which will deliver as much water as will flow in a box 4 feet wide and 1½ feet deep, at a moderate speed, during summer months, would be regarded as a good-sized irrigation feeder in that southern country. In the greater interior basin or central valley, we find other conditions. Here we have a different class of streams. The great Sierra Nevada receives snow upon its summits, which does not melt till May or June and July. The melting of these snows is the source of supply of the streams; so that, while in far southern California, with two or three exceptions, the greater flow of water in the streams is almost gone by June, in this central region it is the period of the height of irrigation, and the streams are flowing at their maximum. Kern river presents about 2000 to 3000 cubic feet of water per second; King's river presents in the maximum flow of the season about twice to three times as much as Kern river; the Tuolumne river about as much as King's. As we go farther north, the Sacramento river presents more than three times as much as the Tuolumne, so that in the northern part of the great valley, where the rainfall on the valley itself is greatest, and, consequently, the necessity for irrigation is least, the irrigation supply increases; and conversely, the greatest area of irrigation in the valley and the greatest necessity for it, is, in general, where the water supply is least.

About 100 years ago irrigation was commenced in California. The Roman Catholic priests, coming from Mexico where irrigation had long been practiced, introduced it. They established missions among the Indians, started cultivation, and by the labor of these Indians built the original irrigation works. The practice of irrigation was extended in San Diego county, as far as we are able to trace, to several thousand acres; in San Bernardino county in the southern interior valley, they thus cultivated and watered, perhaps 2000 acres; and in Los Angeles county there were possibly 3000 acres irrigated under Mexican rule. Traces of the old mission works are found in San Diego, San Bernardino and Los Angeles counties, and as far north as Monterey county.

Then came the gold fever, when canals were dug throughout the foot-hills of the western slope of the Sierra Nevada, for the supply of water for the mining of gold; and these canals have since, in many instances, been turned into feeders for irrigation. Several thousand miles of irrigation ditches have thus been created from old mining ditches. In 1852, a band of Mormons came from Salt Lake into the San Bernardino valley; they bought a Mexican grant rancho there, took possession of some old mission works, constructed others and started irrigating. That was probably the first irrigation colony, on a large scale, composed of others than Mexicans, in California. In 1856, some Missouri settlers went into the valley of Kern river, diverted water from that stream, and commenced irrigation upon a small scale. In 1858, the waters of Cache creek, in the Sacramento valley, were taken out for irrigation. In 1859, the waters of King's river were taken out and utilized for irrigation. These instances represent in general outline the commencement of irrigation in the State. Now we have in the neighborhood of 750,000 or 800,000 acres actually irrigated each year, and that represents what would ordinarily be called an irrigation area of 1,200,000 acres ; and there are commanded by the works—reasonably within the reach of existing canals—an area of about 2,500,000 acres.

In the organization of irrigation enterprises there is great diversity. Commencing with the simplest form, we have a ditch constructed by the individual irrigator for his own use ; we have then successively ditches constructed by associated irrigators without a definite organization, for the service of their own land only ; ditches constructed by regularly organized associations of farmers, with elected officers ; works constructed by farmers who have incorporated under the general laws of the State and issued stock certificates of ownership in the properties, for the service of the stockholders only ; works where incorporations have been formed for the purpose of attaching water stock to lands that are to be sold, bringing in the element of speculation ; then works where the organization has been effected with a view of selling water-rights ; and finally, organizations that are incorporated for the purpose of selling water. There is a great difference between the principles of these methods of organization, and the practical outcome is a great difference in the service of water and in the duty of water furnished by them. In selling water, measurement of volume is made by modules—the actual amount of water delivered is measured—or it is sold by the acre served, or in proportional parts of the total available flow of the season.

The general character of the irrigation works of the State varies very much with the varying conditions under which it is practiced. In the San Joaquin valley, King's river, for instance, comes out of the mountains nearly on a level with the surface of the plain, cutting down not more than a few feet below its banks ; and hence but little labor is required to divert its waters out upon the lands to be irrigated ; but farther north, the Tuolumne, as another example, comes out of the mountains in a deep cañon, and the foot-hills extend far down the plain on each side. It is easily seen, then, that it will require a million or more dollars to divert from the latter stream the amount of water diverted from

King's river by the expenditure of a few months' work, by a small force of the farmers themselves. On King's river, individual and simple coöperative effort is sufficient to bring water enough upon the plains to irrigate thousands of acres, while in the case of the Tuolumne river it is absolutely necessary to have associated capital in large amount—an entirely different principle of organization from that which was originally applied on King's river and the Kern and other rivers in the southern part of the great central valley. In discussions on the subject of irrigation some people have advanced the idea that the works should be undertaken by the farmers, and that capital should have nothing to do with them. That may do very well where the physical conditions will admit of such a course, and where nothing but the farmers' own service depends upon it; but the great majority of the streams of California are of such a character that the work of the farmers can avail nothing. There must be strong associations and large capital. For this purpose special laws are required. On the Santa Aña, in San Bernardino county, water has been easily diverted, and such is the case with every stream in the interior valley of San Bernardino and Los Angeles counties.

Capital for the first works was not required. The water was procured by primitive methods and the works were simple. But in San Diego, an entirely different condition of affairs prevailed. There the waters are back in the mountains, twenty or twenty-five miles from the coast, and the irrigable lands are close along the coast, or within ten or twelve miles of it. To bring the water out of these mountains requires the construction of ditches following the mountain sides for 20 to 35 miles. But simple ditches do not answer, because of the great quantity of water lost from them. So the companies have resorted to fluming, and even to lining the ditches with cement. Thus in San Diego, individual effort is out of the question. Farther north again, in the great interior valley, King's river is a stream where coöperative and individual effort have been efficient, although it requires a greater amount of capital there than in the southern interior valley. In the southern interior valley, perhaps, $10,000 would often build a ditch and divert all the water that the supply would furnish. On King's river the works have cost from $15,000 to $80,000 each; on Kern river the works have cost from $15,000 to $250,000 each; and on the Tuolumne they will cost from $1,000,000 to $1,200,000 apiece. On Merced river, the cost has been $800,000 for one work. Taking the streams from San Joaquin river north, that come out of the Sierra Nevada, up to the northern end of the valley where the Sacramento river enters it, every important stream comes into the valley within a deep gorge. The beds of several of the northern streams are so filled up with mining debris that diversion from them would be comparatively easy, but in their natural state there is not an important stream north of the San Joaquin which could be utilized for irrigation by any other means than through the agency of capital in large amount. On the west side of this great valley the tillable strip is comparatively narrow. It is on the lee side of the coast range of mountains. Precipitation is made first on the seaward face of the Coast Range, and then crosses the valley, dropping upon the inland face of the outer range very little more than upon the valley itself, where the precipitation is only about 10 inches. So that we have no streams coming out of the Coast Range into the southern part of the interior valley specially noteworthy as irrigation feeders. But as we go northward the Coast Range becomes wider, and the big mountain basin containing Clear Lake furnishes a large supply of water to Cache Creek, probably enough for 10,000 acres. Stony Creek flows between two ridges of the Coast Range, and out on to the plains, furnishing about the same amount of water; but still there are no streams from the Coast Range into the valley that are comparable with those of the Sierra Nevada. In the northeastern corner of the State, on the great plains of Modoc, we have the Pitt river, a stream of very considerable volume, but its waters are in comparatively deep channels, not very well adapted to diversion, and the consequence is, they have been utilized to a very small extent, only on small bottom-land farms. The whole stream can be utilized, however, and the country is thirsting for water.

The practice of irrigation in California is as diverse as it could well be. California, as you know, covers a very large range in latitude, but a greater range in the matter of climate and adaptability to the cultivation of crops. In the southern portion of the State, the orange and the banana and many other semi-tropical fruits flourish. In some localities along the foot-hills of the Sierra Nevada, also, those fruits flourish, particularly the orange and the lemon. In the valley of San Joaquin, wheat is grown by irrigation, and in some places profitably, and in Kern county quite profitably (were it not for high transportation charges), because the cost of distributing and applying water has been reduced to a minimum. There the lands have been laid out with as much care and precision as the architect would lay out the stones in a building and the mason would place them. Irrigation is conducted in some Kern river districts with the greatest ease, scarcely requiring the use of the shovel. The lands are so laid off with the check levels that by simply opening gates in the proper order, as the irrigation superintendents know how, the waters flow out and cover the successive plats or "checks" in their order, without leaving any standing water, and finally flowing off without material waste. This is the perfection of irrigation by the broad or submerging system,—a method wherein the slope of the ground is first ascertained, platted by contours, and the checks to hold the water, constructed with scrapers, are then run out on slight grade contours—not perfectly level, but on very gentle slopes.

There is no portion of the far southern part of the State where the check method is applied as it is in Kern county. The practice in San Bernardino is to irrigate entirely by running water in rills between the rows of plants. Orange trees planted 24 to 30 feet apart are irrigated by rills in plough furrows, 5 to 8 between rows, down the slope of the orchard, which slope varies from about 1 foot in a hundred to 4 or 5 in a hundred. In Los Angeles county they make banks about a foot high around each individual tree, forming basins 5 or 6 to 10 or 12 feet in diameter according to the size of the tree. Into these the water is conducted by a ditch, and the basin being filled, the water is allowed to remain and soak away. The low, nearly flat valley lands, when irrigated, are generally divided into square "checks," without respect to the slope of the ground, and the surface is simply flooded in water standing 6 inches to a foot in depth.

In the northern part of the State, in Placer and Yuba counties, clover is grown on hills having side slopes of 10 to 15 feet in a hundred, and irrigated in plough furrows cut around on contours —which furrows are about 5 to 10 feet apart horizontally—and the water is allowed to soak into the ground from each such furrow.

These are the five principal methods of applying water: by the check system; by rills; by the basin method; by the basin method as applied to low valleys; and by contour ditches on hill sides. The method selected for any particular locality is determined not alone by the crop to be cultivated, but also by the slope of the land and the character of the soil. For instance, on lands where oranges are cultivated, in the southern part of the State, where rills are most generally used, water cannot be applied by the flooding system, for the reason that irrigation would be followed by cracking of the soil, so that the trees would be killed. It is necessary on such land to cultivate immediately after irrigation, and the method of application is governed more by the soil than by the character of the crop.

We find in California very marked and important effects following irrigation. For instance, taking the great plains of Fresno, in the San Joaquin valley: when irrigation commenced there twenty years ago, it was 70 to 80 feet down to soil water—absolutely dry soil for nearly 80 feet—and it was the rule throughout the great plain, 20 miles in width and 25 miles in length, that soil water was beyond the reach of the suction pump; now, in places, water stands on the surface, rushes grow, mosquitos breed, malarial fevers abound, and the people are crying for drainage; and lands, whose owners paid from five to twenty dollars per acre for the right to receive water, now need drainage, and irrigation is considered unnecessary. The amount of water taken from King's river which was, a few years ago, regarded as not more than sufficient for one tenth of the land immediately commanded and that seemed to require it, is now applied to a fourth of the whole area; so that if irrigation keeps on, the time will come when the whole country will require draining.

In a district, where water is applied by the broad method, I saw in 1877 enough water, by actual measurement of flow, put on 20 acres of land to cover it 18 feet deep, in one season, could it all have been retained upon it. It simply soaked into the ground, or flowed out under the great plain. Taking cross sections of this country, north and south and east and west, I found that where the depth to soil water had, before irrigation, been about 80 feet, it was then 20, 30, 40 or 60 and more feet down to it. The soil water stood under the plain in the form of a mountain, the slope running down 40 to 50 feet in a few miles on the west and north. On the south and southwest the surface of this water-mountain was much more steep. In the Kern river country, we have a somewhat similar phenomenon. Irrigation, in the upper portion of the Kern delta, affects the water in the wells 6 or 8 miles away. As I remember the effect is felt at the rate of about a mile a day, that is to say, when water is used in irrigating the upper portion of the delta, or of Kern island, as it is called, the wells commence to rise a mile away in twenty-four hours, and five miles away in perhaps five days.

In the southern portion of the State, in San Bernardino county, at Riverside, we find no such effect at all. There it was 70 to 90 feet to soil water before irrigation and it is, as a general rule, 70 to 90 feet still. Water applied on the surface in some places has never even wet the soil all the way down, and wells dug there, after irrigation had been practiced for years, have pierced dry ground for 25 or 30 feet before getting down to where soil waters have wetted it from below. The consequences of these phenomena are twofold. In the first place, in the country that fills up with water, the duty of water—the quantity of land which a given amount of water will irrigate—has increased. Starting with a duty of not more than 25 acres to a cubic foot of water per second, we now find that, in some localities, this amount irrigates from 100 to 160 acres; and that some lands no longer require irrigating. In the southern portion of the State, however, the cubic foot of water irrigates no more than at first, and it is scarcely possible that it will ever irrigate much more. The saving, as irrigation goes on in the far southern portion of the State, will be effected chiefly through the better construction of canals and irrigation works of delivery and distribution. In Tulare valley, the duty of water will increase as the ground fills up.

In Fresno, a county which was regarded as phenomenally healthy, malarial fevers now are found, while in San Bernardino, at Riverside, such a thing is rarely known. Coming to Bakersfield, a region which before irrigation commenced was famed for its malarial fevers—known as unhealthful throughout all the State—where soil water was originally within 15 feet of the surface, irrigation has almost entirely rid it of the malarial effects. Chills and fever are rare now, where before irrigation they were prevalent. What is the reason that where chills and fever prevailed, irrigation has made a healthful country, while where chills and fevers were not known, irrigation has made it unhealthful? I account for it in this way: in the Kern river country before irrigation was extensively introduced, there were many old abandoned river channels and sloughs, overgrown with swamp vegetation and overhung by dense masses of rank-growing foliage.

Adjacent lands were in a more or less swampy condition; ground waters stood within 10 or 20 feet of the surface, and there was no hard-pan or impermeable stratum between such surface and these waters. In other words, general swampy conditions prevailed, and malarial influences followed by chills and fevers were the result. Irrigation brought about the clearing out of many of these old channel ways, and their use as irrigating canals. The lands were cleared off and cultivated, fresh water was introduced through these channels from the main river throughout the hot months, and the swamp-like condition of the country was changed to one of a well-tilled agricultural neighborhood with streams of fresh water flowing through it; and the result, as I have said, was one happy in its effect of making the climate salubrious and healthful.

Considering now the case of the King's river or the Fresno country, the lands there were a rich alluvial deposit, abounding in vegetable matter which for long ages perhaps had been, except as wetted by the rains of winter, dry and dessicated. Soil water was deep below the surface. Then irrigation came. Owing to the nature of the soil, the whole country filled up with the water. Its absorptive qualities being great and its natural drainage defective, the vegetable matter in the soil, subjected to more or less continued excessive moisture, has decayed. The fluctuation of the surface of the ground waters at different seasons of the year—such surface being at times very near to the ground surface, and at other times 5 or 6 feet lower—has contributed to the decaying influences which the presence of the waters engendered. The result has been, when taken with the general overgrowth of the country with vegetation due to irrigation, a vitiation of the atmosphere by malarious outpourings from the soil. The advantage of the pure atmosphere of a wide and dry plain has been lost by the miasmatic poisonings arising from an overwet and ill-drained neighborhood, with the results, as affecting human healthfulness, of which I have already spoken. The remedy is of course to drain the country. The example is but a repetition of experiences had in other countries. The energy and pluck of Californians will soon correct the matter.

George P. Marsh, in his "Man and Nature," laid it down as a rule that an effect of irrigation was to concentrate land holdings in a few hands, and he wrote an article, which was published in one of our Agricultural Department reports, in which he rather deprecates the introduction of irrigation into the United States, or says that on this account it should be surrounded by great safeguards. He cited instances in Europe, as in the valley of the Po, where the tendency of irrigation had been to wipe out small land holdings, and bring the lands into the hands of a few of the nobility. He cited but one country where the reverse had been the rule, which was in the south and east of Spain, and pointed out the reason, as he conceived it, that in south and south-eastern Spain the ownership of the water went with the land and was inseparable from it, under ancient Moorish rights. It is a fact, that where the ownership of water goes with the land, it prevents centering of land ownership into few hands, after that ownership is once divided among many persons, in irrigated regions. But Mr. Marsh overlooked one thing in predicting harm in our country ; that is, that it will be many years before we will get such a surplus of poor as to bring about the result he feared. In California, the effect of irrigation has not been to center the land in the hands of a few. On the contrary, the tendency has been just the other way. When irrigation was introduced it became possible for small land holders to live. In Fresno county, there are many people making a living for a family, each on 20 acres of irrigated land, and the country is divided into 20 and 40-acre tracts and owned in that way. In San Bernardino the same state of things prevails. Before irrigation, these lands were owned in large tracts, and it was not an uncommon thing for one owner to have 10,000 to 20,000 acres of land. So that the rule in California, which is the effect of irrigation, is to divide land holdings into small tracts, and in this respect, also, irrigation is a blessing to the country. It enables large owners to cut up their lands and sell out to the many. Land values have advanced from $1.25 in this great valley to $50, $150 and even $250 per acre, simply by attaching to the land the right to take or use water, paying in addition an annual rental : in the southern portion of the State, they have advanced from $5 and $10 to $500 and even $1000 an acre, where the land has the right to water ; and many calculations have been made and examples cited by intelligent and prominent people, to show that good orange land or good raisin-grape land with sufficient water supply is well worth $1000 an acre. Water rights run up proportionately in value. A little stream flowing an inch of water—an amount that will flow through an inch square opening under four inches of pressure—in the southern part of the State, is held at values ranging from $500 to $5000. Such a little stream has changed hands at $5000, and not at boom prices either. In the interior prices are much less, being from about a quarter to a tenth of those in the far southern part of the State.

Fully one fourth of the United States requires irrigation. When I say that, I mean that fully one fourth the tillable area of our country requires irrigation, in order to support such a population as, for instance, Indiana has. The irrigated regions of Italy support populations of from 250 to 300 people to the square mile; of south France, from 150 to 250 people to the square mile; of southeast Spain, from 200 to 300. When we have 50 to 100 to the square mile in an agricultural region we think we have a great population.

The great interior valley of California will not support, without irrigation, an average of more than 15 to 20 people per square mile. Irrigate it and it will support as many as any other portion of the country—reasonably it will support 200 to the square mile. I have no doubt that the population will run up to ten or twelve millions in that one valley, and there are regions over this country from the Mississippi to the Pacific, millions of acres, that can be made to support a teeming population by the artificial application of water. And why has it not been done before? Simply for the reason that there is a lack of knowledge of what can be done and a lack of organization and capital to carry out the enterprises.

The government has recently placed at the disposal of the United States Geological Survey an appropriation for the investigation of this subject, to ascertain how irrigation can be secured, the cost of irrigation works, and point out the means for irrigation, in the arid regions. It is one of the wisest things Congress ever did; wise in the time and in the subject. The time will soon come when the question would have been forced upon the country, and the wisdom of preparing for that time cannot be too highly commended.


U.S. G
J.W
36°
83°
M
Laur
Moneyb
50'

U.S. GEOLOGICAL SURVEY
J.W. POWELL, DIRECTOR

NORTH CAROLINA-TENNESSEE
ASHEVILLE SHEET

SECTION FROM THE CUMBERLAND PLATEAU TO THE BLUE RIDGE

ROUND ABOUT ASHEVILLE.

BY BAILEY WILLIS.

A BROAD amphitheatre lies in the heart of the North Carolina mountains which form its encircling walls; its length is forty miles from north to south and its width ten to twenty miles. At its southern gate the French Broad river enters ; through the northern gate the same river flows out, augmented by the many streams of its extensive watershed.

From these water-courses the even arena once arose with gentle slope to the surrounding heights and that surface, did it now exist, would make this region a very garden, marked by its genial climate and adequate rainfall. But that level floor exists no longer; in it the rivers first sunk their channels, their tributaries followed, the gullies by which the waters gathered deepened, and the old plain was thus dissected. It is now only visible from those points of view from which remnants of its surface fall into a common plane of vision. This is the case whenever the observer stands upon the level of the old arena; he may then sweep with a glance the profile of a geographic condition which has long since passed away.

Asheville is built upon a bit of this plain between the ravines of the French Broad and Swannanoa rivers, now flowing 380 feet below the level, and at the foot of the Beau-catcher hills; toward which the ground rises gently. The position is a commanding one, not only for the far reaching view, but also as the meeting place of lines of travel from north, south, east, and west. Thus Asheville became a town of local importance long before railroads were projected along the lines of the old turnpikes. The village was the center of western North Carolina, as well of the county of Buncombe, and was therefore appropriately the home of the district Federal court. A May session of the court was in progress nine years ago when I rode up the muddy street from the Swannanoa valley. Several well-known moonshiners were on trial, and the town street was crowded with their sympathizers, lean mountaineers in blue and butternut homespun. Horses were hitched at every available rack and fence, and horse trading was active. Whiskey was on trial at other bars than that of the court, and the long rifle, powder-horn and pouch had not been left in the mountains. To a "tenderfoot" (who had the day before been mistaken for a rabbit or a revenue officer !) the attentions of the crowd were not reassuring.

The general opinion was, I felt, akin to that long afterward expressed by Groundhog Cayce: "It air an awful thing ter kill a man by accident;" and I staid but a very short time in Asheville.

Riding away toward the sunset, I traversed the old plain without seeing that it had had a continuous surface. I noted the many gullies, and I lost in the multitude of details the wide level from which they were carved. That the broader fact should be obscured by the many lesser ones is no rare experience, and perhaps there is no class of observations of which this has been more generally true than of those involved in landscape study. But when once the Asheville plain has been recognized, it can never again be ignored. It enters into every view, both as an element of beauty and as evidence of change in the conditions which determine topographic forms. Seldom in the mountains can one get that distance of wooded level, rarely is the foreground so like a gem proportioned to its setting; all about Asheville one meets with glimpses of river and valley, sunken in reach beyond reach of woodland which stretch away to the blue mountains. The even ridges form natural roadsites, and in driving one comes ever and anon upon a fresh view down upon the stream far across the plain and up to the heights. And to the student of Appalachian history, the dissected plain is a significant contradiction of the time honored phrase, "the everlasting hills." That plain was a fact, the result of definite conditions of erosion ; it exists no more in consequence of changes. What were the original conditions? In what manner have they changed? Let us take account of certain other facts before suggesting an answer. Of the mountains which wall the Asheville amphitheatre, the Blue Ridge on the east and the Unaka chain on the west are the two important ranges. The Blue Ridge forms the divide between the tributaries of the Atlantic and those of the Gulf of Mexico, and the streams which flow westward from it all pass through the Unaka chain. It would be reasonable to suppose that the rivers rose in the higher and flowed through the lower of the two ranges, but they do not. The Blue Ridge is an irregular, inconspicuous elevation but little over 4000 feet above the sea; the Unaka mountains form a massive chain from 5000 to 6500 feet in height. That streams should thus flow through mountains higher than their source was once explained by the assumption that they found passage through rents produced by earth convulsions; but that vague guess marked the early and insufficient appreciation of the power of streams as channel cutters, and it has passed discredited into the history of our knowledge of valley-formation. That rivers carve out the deepest cañons, as well as the broadest valleys, is now a truism which we must accept in framing hypotheses to account for the courses of the French Broad and other similar streams. Moreover, since waters from a lower Blue Ridge could never of their own impulse have flowed over the higher Unaka, we are brought to the question, was the Blue Ridge once the higher, or have streams working on the western slope of the Unaka range (when it was a main divide), worn it through from west to east, capturing all that broad watershed between the two mountain ranges? Either hypothesis is within the possibility of well established river action, and both suggest the possibility of infinite change in mountain forms and river systems. Without attempting here to discriminate between these two hypotheses, for which a broader foundation of facts is needed, let us look at the channel of the French Broad below Asheville, in the river's course through the range that is higher than its source. Descending from the old plain into the river's ravine, we at once lose all extended views and are closely shut in by wooded slopes and rocky bluffs. The river falls the more rapidly as we descend, and its tributaries leap to join it, the railroad scarce finding room between the rocks and the brawling current. The way is into a rugged and inhospitable gorge whose walls rise at last on either hand into mountains that culminate some thirty miles below Asheville. At Mountain Island the waters dash beautifully over a ledge of conglomerate and rush out from a long series of rapids into the deep water above Hot Springs. Beyond the limestone cove in which the springs occur, the valley, though narrow still, is wider and bottom lands appear. Thus the water gap of the French Broad through the Unakas is narrow and rugged, the river itself a tossing torrent; but had we passed down other streams of similar course, we should have found them even more turbulent, their channels even more sharply carved in the hard rocks. On Pigeon river there are many cliffs of polished quartzite, and on the Nolichucky river a V-shaped gorge some eight miles long is terraced where the ledges of quartzite are horizontal and is turreted with fantastic forms where the strata are vertical. Where the river valleys are of this sharp cut character in high mountains, the abrupt slopes, cliffs and rocky pinnacles are commonly still more sharply accented in the heights. The Alpine tourist or the mountaineer of the Sierras would expect to climb from these cañons to ragged combs or to scarcely accessible needle-like peaks. But how different from the heights of the Jungfrau are the "balds" of the Unakas! like the ice-worn granite domes of New England, the massive balds present a rounded profile against the sky. Although composed of the hardest rock, they yet resemble in their contours, the low relief of a limestone area. Broad, even surfaces, on which rocky outcrops are few and over which a deep loam prevails, suggest rather that one is wandering over a plain than on a great mountain; yet you may sweep the entire horizon and find few higher peaks. The view is often very beautiful, it is far-reaching, not grand. No crags tower skyward, but many domes rise nearly to the same heights, and dome-like, their slopes are steepest toward the base. The valleys and the mountains have exchanged the characters they usually bear ; the former are dark and forbidding, wild and inaccessible, the latter are broad and sunlit of softened form, habitable and inhabited. All roads and villages are on the heights, only passing travelers and those who prey upon them frequent the depths.

These facts of form are not local, they are general : all the streams of the Unaka mountains share the features of the French Broad Cañon, while peaks like Great Roan, Big Bald, Mt. Guyot, are but examples of a massive mountain form common throughout the range.

Thus the Unaka chain presents two peculiar facts for our consideration ; it is cut through by streams rising in a lower range, and its profiles of erosion are convex upward not downward.

If we follow our river's course beyond the Unaka chain into the valley of East Tennessee we shall still find the channel deeply cut ; here and there bottomlands appear, now on one side, now on the other, but the banks are more often steep slopes or vertical cliffs from fifty to one hundred feet high. The creeks and brooks meander with moderate fall through the undulating sur face of the valley, but they all plunge by a more or less abrupt cascade into the main rivers. It is thus evident that the tributaries cannot keep pace with the rivers in channel-cutting, and the latter will continue to sink below the surface of general degradation until their diminished fall reduces their rate of corrasion below that of the confluent streams.

If from topographic forms we turn to consider the materials, the rocks, of which they are composed, we shall find a general rule of relation between relative elevation and rock-hardness. Thus the great valley of East Tennessee has a general surface 3000 feet below the mean height of the Unakas: it is an area of easily soluble, often soft, calcareous rocks, while the mountains, consist of the most insoluble, the hardest, silicious rocks. East of the Unakas the surface is again lower, including the irregular divide, the Blue Ridge; here also, the feldspathic gneisses and mica schists are, relatively speaking, easily soluble, and non-coherent. What is thus broadly true is true in detail, also where a more silicious limestone or a sandstone bed occurs in the valley it forms a greater or less elevation above the surface of the soft rocks; where a more soluble, less coherent stratum crops out in the mountain mass, a hollow, a cove, corresponds to it. Of valley ridges, Clinch mountain is the most conspicuous example; of mountain hollows the French Broad valley at Hot Springs, or Tuckaleechee Cove beneath the Great Smoky mountain, is a fair illustration.

But impassive rock-hardness, mere ability to resist, is not adequate to raise mountains, nor is rock-softness an active agent in the formation of valleys. The passive attitude of the rocks implies a force, that is resisted, and the very terms in which that attitude is expressed suggest the agent which applies the force. Hardness, coherence, insolubility,—these are terms suggestive of resistance to a force applied to wear away, to dissolve, as flowing water wears by virtue of the sediment it carries and as percolating waters take the soluble constituent of rocks into solution. And it is by the slow mechanical and chemical action of water that not only cañons are carved but even mountain ranges reduced to gentle slopes.

If we designate this process by the word "degradation," it follows from the relation of resistance to elevation in the region under discussion that we may say: The Appalachians are mountains of differential degradation; that is, heights remain where the rocks have been least energetically acted on, valleys are carved where the action of water has been most effective.

In order that the process of degradation may go on it is essential that a land mass be somewhat raised above the sea, and, since the process is a never-ceasing one while streams have sufficient fall to carry sediment, it follows that, given time enough, every land surface must be degraded to a sloping plain, to what has been called a base level.

With these ideas of mountain genesis and waste, let us consider some phases of degradation in relation to topographic forms; and in doing so I cannot do better than to use the terms employed by Prof. Wm. M. Davis.

When a land surface rises from the ocean the stream systems which at once develope, are set the task of carrying back to the sea all that stands above it. According to the amount of this alloted work that streams have accomplished, they may be said to be young, mature or aged; and if, their task once nearly completed, another uplift raise more material to be carried off, they may be said to be revived. These terms apply equally to the land-surface, and each period of development is characterized by certain topographic forms.

In youth simple stream systems sunk in steep walled cañons are separated by broad areas of surface incompletely drained. In maturity complex stream systems extend branches up to every part of the surface; steep slopes, sharp divides, pyramidal peaks express the rapidity with which every portion of the surface is attacked.

In old age the gently rolling surface is traversed by many quiet flowing streams; the heights are gone, the profiles are rounded, the contours subdued. In the first emergence from the sea the courses of streams are determined by accidents of slope, it may be by folding of the rising surface into troughs and arches. During maturity the process of retrogressive erosion, by which a stream cuts back into the watershed of a less powerful opponent stream, adjusts the channels to the outcrops of soft rocks and leaves the harder strata as eminences. In old age this process of differential degradation is complete and only the hardest rocks maintain a slight relief.

Suppose that an aged surface of this character be revived: the rivers hitherto flowing quietly in broad plains will find their fall increased in their lower courses; their channels in soft rock will rapidly become cañons, and the revived phase will retreat up stream in the same manner that the cañons of youth extended back into the first uplifted mass. If the area of soft rocks be bounded by a considerable mass of very hard rocks, it is conceivable that a second phase of age, a base level, might creep over the valley while yet the summits of the first old age remained unattacked, and should perchance revival succeed revival the record of the last uplift might be read in sharp cut channels of the great rivers, while the forms of each preceding phase led like steps to the still surviving domes of that earliest old age.

Is there aught in these speculations to fit our facts? I think there is. We have seen that our mountains and valleys are the result of differential degradation, and that this is not only broadly true but true in detail also. This is evidence that streams have been long at work adjusting their channels, they have passed through the period of maturity.

We have climbed to the summits of the Unakas and found them composed of rocks as hard as those from which the pinnacle of the Matterhorn is chiseled; but we see them gently sloping, as a plain. These summits are very, very old.

We have recognized that dissected plain, the level of the Asheville amphitheatre, now 2,400 feet above the sea; it was a surface produced by subaerial erosion, and as such it is evidence of the fact that the French Broad River, and such of its tributaries as drain this area, at one time completed their work upon it, reached a base level. That they should have accomplished this the level of discharge of the sculpturing streams must have been constant during a long period, a condition which implies either that the fall from the Asheville plain to the ocean was then much less than it now is, or that through local causes the French Broad was held by a natural dam, where it cuts the Unaka chain.

If we should find that other rivers of this region have carved the forms of age upon the surfaces of their intermontane valleys, and there is now some evidence of this kind at hand, then we must appeal to the more general cause of base-levelling and accept the conclusion that the land stood lower in relation to the ocean than it now does. Furthermore, we have traversed the ravines which the streams have cut in this ancient plain and we may note on the accompanying atlas sheet that the branches extend back into every part of it; the ravines themselves prove that the level of discharge has been lowered, the streams have been revived; and the wide ramification of the brooks is the characteristic of approaching maturity.

We have also glanced at the topography of the valley and have found the rivers flowing in deep-cut simple channels which are young, and the smaller streams working on an undulating surface that is very sensitive to processes of degradation.

The minor stream systems are very intricate and apparently mature, but they have not yet destroyed the evidence of a general level to which the whole limestone area was once reduced, but which now is represented by many elevations that approach 1,600 feet above the sea. Here then in the valley are young river channels, mature stream systems and faint traces of an earlier base level, all of them more recent than the Asheville level, which is in turn less ancient than the dome-like summits of the Unakas.

What history can we read in these suggestive topographic forms and their relations?

The first step in the evolution of a continent is its elevation above the sea. The geologist tells us that the earliest uplift of the Appalachian region after the close of the Carboniferous period was preceded or accompanied by a folding of the earth's crust into mountainous wave-like arches; upon these erosion at once began and these formed our first mountains. Where they were highest the geologist may infer from geologic structure and the outcrops of the oldest rocks; but the facts for that inference are not yet all gathered and it can only be said that the heights of that ancient topography were probably as great over the valley of Tennesseee as over the Unaka chain. The positions of rivers were determined by the relations of the arches to each other and, as they were in a general way parallel, extending from northeast to southwest, we know that the rivers too had northeast–southwest courses. From that first drainage system the Tennessee river, as far down as Chattanooga, is directly descended, and when the geologic structure of North Carolina and East Tennessee is known, we may be able to trace the steps of adjustment by which the many waters have been concentrated to form that great river. At present we cannot sketch the details, but we know that it was a long process and that it was accompanied by a change in the *raison d'être* of the mountain ranges. The first mountains were high because they had been relatively raised; they gave place to hills that survived because they had not been worn down. A topography of differential uplift gave place to one of differential degradation. And to the latter the dome-like "balds" of the Unakas belong. Those massive summits of granite, quartzite and conglomerate are not now cut by running waters; they are covered with a mantel of residual soil, the product of excessively slow disintegration, and they are the remnants of a surface all of which has yielded to degradation, save them. In time the streams will cut back and carve jagged peaks from their masses, but standing on their heights my thought has turned to the condition they represent—the condition that is past. And thus in thought I have looked from the Big Bald out on a gently sloping plain which covered the many domes of nearly equal height and stretched away to merge on the horizon in the level of the sea. That, I conceive, was the first base level plain of which we have any evidence in the Appalachians and from that plain our present valleys have been eroded. The continental elevation must then have been 3,000 or 4,000 feet less than it is now, and the highest hills were probably not more than 2,500 feet above the sea. This was perhaps a period of constant relation between sea and land, but it was succeeded by one during which the land slowly rose. The rivers, which had probably assumed nearly their present courses, were revived; the important channels soon sank in cañons, the tributaries leaped in rapids and cut back into the old base level. The region continued to rise during a period long enough to produce the essential features of the mountain ranges of to-day; then it stood still in relation to the sea or perhaps subsided somewhat, and the French Broad and probably other rivers made record of the pause in plains like that about Asheville. Again the land rose slowly; again it paused, and rivers, working always from their mouths backward, carved a base-level in the limestones of the great valley; but before that level could extend up through the gorges in the Unakas, the continent was raised to its present elevation, the streams responded to the increased fall given them and the rivers in the valley began to cut their still incomplete cañons.

Are we not led step by step from these latest sharply cut channels up stream through the chapters of erosion to the still surviving domes of an early old age? Let us sum up the history we have traced. There is reason to believe that:

1st. The consequent topography of the earliest Appalachian uplift was entirely removed during a prolonged period of erosion and was replaced by a relief of differential degradation.

2d. The balds of the Unakas represent the heights of that first-known approach to a base-level.

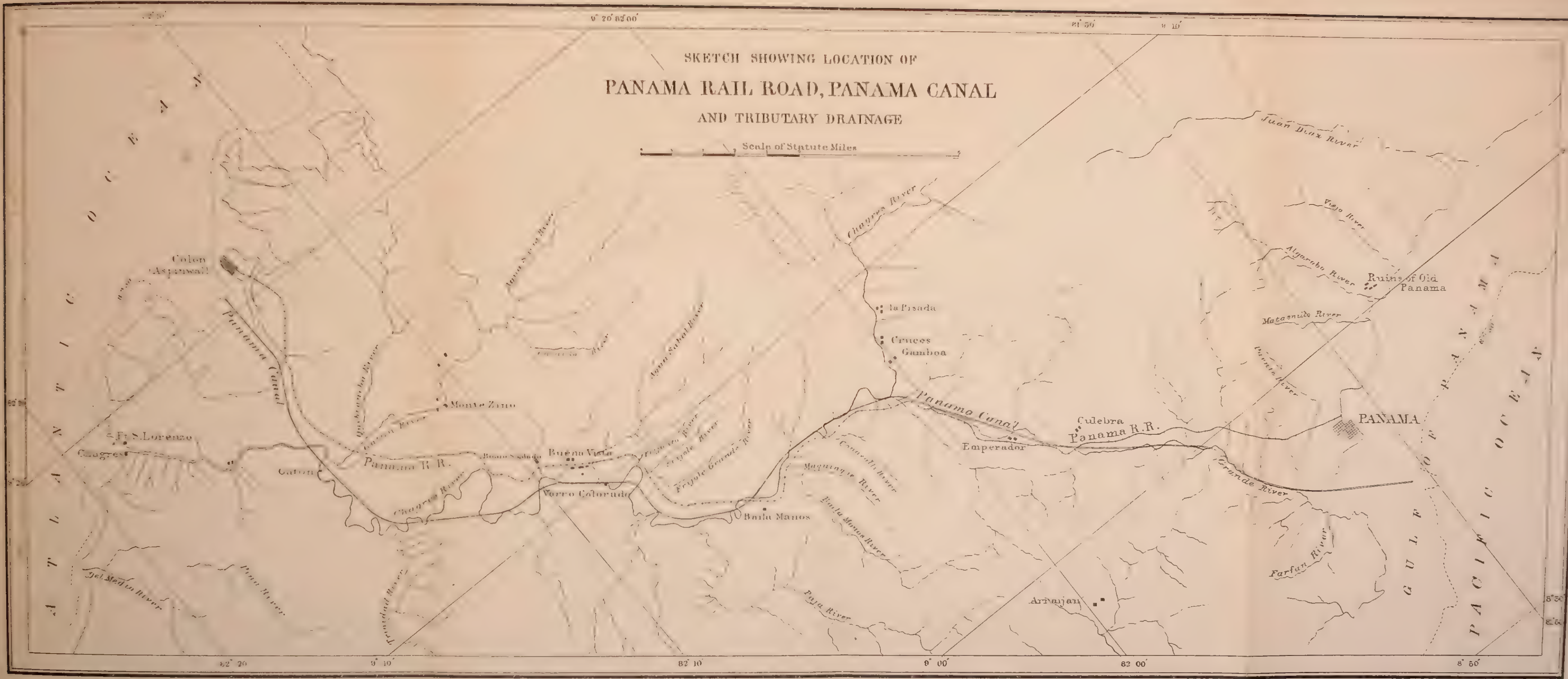
3d. The topography of the region has been revived by a general, though not necessarily uniform, uplift of 3,000 feet or more, divided by two intervals of rest; during the first of these the Asheville base-level was formed; during the second, the valley alone was reduced.

4th. The latest movement of the uplift has been, geologically speaking, quite recent, and the revived streams have accomplished but a small part of their new task.

These conclusions are reached on the observation of a single class of facts in one district; they must be compared with the record of continental oscillation on the sea coasts, in the deposits of the coastal plain, and in the topography of other districts.

The history of the Appalachians is written in every river system and on every mountain range, but in characters determined for each locality by the local conditions. Only when the knowledge, to which every tourist may contribute, is extended over the entire region shall we know conclusively the whole story.


82°2
9°2


SKETCH SHOWING LOCATION OF
PANAMA RAIL ROAD, PANAMA CANAL
AND TRIBUTARY DRAINAGE
Scale of Statute Miles
ATLANTIC OCEAN
Colon
Aspinwall
Panama Canal
Ft. S. Lorenzo
Chagres
Gatun
Panama R.R.
Monte Zino
Buena Vista
Chagres River
Cerro Colorado
Baila Manos
Chagres River
la Pisada
Cruces
Gamboa
Panama Canal
Culebra
Panama R.R.
Emperador
Juan Diaz River
Algarobo River
Ruins of Old Panama
Matasnillo River
PANAMA
Grande River
Farfan River
Arraijan
Paja River
GULF OF PANAMA
PACIFIC OCEAN
82° 20
9° 10
82° 10
9° 00
82° 00
8° 50

A TRIP TO PANAMA AND DARIEN.

By Richard U. Goode.

The Government of the United States of Colombia in its act of Concession to the Panama Canal Company provided that it should give to the latter "*gratuitement et avec toutes les mines qu'ils pourront contenir*" 500,000 hectares of land.

Some of the conditions attached to this grant were, that the land should be selected within certain limits and surveyed by the Canal Company; that a topographical map should be made of the areas surveyed and that an amount equal to that surveyed for the canal should also be surveyed for the benefit of the Colombian Government. It was also further agreed that it would not be necessary to complete the canal before any of the land should be granted, but that it would be given at different times in amounts proportional to the amount of work accomplished.

Thus in 1887, the Government agreed to consider that one-half of the work on the canal had been finished and that the canal was consequently entitled to 250,000 hectares of land, upon the completion of the necessary surveys, etc.

The land was eventually chosen partly in Darien and partly in Chiriqui as follows:

In Darien three lots, one between the Paya and Mangle rivers, one between the Maria and Pirri rivers, the two amounting to 100,000 hectares, and one lot of 25,000 hectares between the Yape and Pucro rivers.

In Chiriqui, which is a Province of Panama just east of Costa Rica, two lots were chosen amounting to 125,000 hectares, one between the Sigsola and Rabalo rivers, and the other between the Catabella and San Pedro rivers.

The Canal Company wanted the title to the land in order that it might be used as collateral security in bolstering up the finances of the corporation, and the Colombian Government was doubtless very willing to let the Canal Company have this amount or as much more as was wanted, both parties being equally aware of the valueless character of the land for any practical purposes.

My services were engaged in 1888 in connection with the astronomical work incident to the survey of these grants and it was intended that I should visit both Darien and Chiriqui, but the contract term expired about the time of the completion of the work in Darien, which was taken up first, and it was deemed prudent for various reasons, the chief of them being the unhealthiness of the locality at that season of the year, about the middle of April, not to remain longer on the Isthmus. If it had been possible to work as expeditiously as in this country there would have been ample time to have completed the necessary astronomical work for both surveys, and without understanding men and methods peculiar to a tropical country I started out with this expectation, but soon found out that any efforts looking towards expediting any particular matter were not only useless but were detrimentally reactive upon the person putting forward such efforts. Thus it was nearly the first of March before I reached Darien, having sailed from New York a month previously. Passage was had from Panama to Darien in a steamer chartered for the purpose. Sailing across the Bay of Panama and entering the Tuyra River at Boca Chica, we ascended the river as far as the village Real de St. Marie. At this point the steamer was abandoned and further transportation was had in canoes.

Darien is a province of the State of Panama and its boundaries as given by Lieut. Sullivan in his comprehensive work on "Problem of Interoceanic Communication," are as follows: "The Atlantic coast line is included between Point San Blas and Cape Tiburon; that of the Pacific extends from the mouth of the Bayano to Point Ardita. The eastern boundary is determined by the main Cordillera in its sweep across the Isthmus from a position of close proximity to the Pacific, near Point Ardita, to a similar position near Tiburon, on the Atlantic. The valleys of the Mandinga and Mamoni-Bayano determine its western limit."

The Darien hills as seen from the Atlantic side present to the view an apparently solid ridge of mountains, although there are in reality many low passes which are concealed by projecting spurs.

The dividing ridge hugs close to the Atlantic, and the rivers, of which there are a great many on this side, plunge abruptly to the sea. On the Pacific side the rivers have a much longer distance to flow before reaching the sea, and the territory bordering on the ocean is low and swampy. The tidal limit of the Tuyra River is nearly fifty miles from its mouth, and on this river and many of its tributaries one can travel many miles inland before ground sufficiently solid to land upon can be found. The vegetation within this low lying area is thick and closely matted together, and this fact taken in connection with the swampy character of the ground, makes travel on foot through any portion of it exceedingly difficult. Therefore the various rivers, which form a very complex system and penetrate everywhere are the natural highways of the country. The chief rivers on the Pacific side are the Tuyra and Boyano with their numerous tributaries and on the Atlantic watershed is the Atrato.

A peculiarity noticed at Real de St. Marie, which is at the junction of the Pyrrhi and Tuyra rivers and at which point the tide has a rise and fall of twelve or fifteen feet, was that at low tide it was impossible to enter the mouth of the Pyrrhi with a boat, while five or six miles up the stream there was always a good supply of flowing water and at double that distance it became a mountain torrent.

Outside of the swampy area the character of the country is rough and mountainous. The valleys are narrow and the ridges exceedingly sharp, the natural result of a great rain fall. The hills are able to resist the continued wasting effect of the vast volumes of descending water only by their thick mantle of accumulated vegetation, and were it not for this protection the many months of continuous annual rain would long ago have produced a leveling effect that would have made unnecessary the various attempts of man to pierce the Isthmian mountains and form an artificial strait.

The ridges are sometimes level for a short distance, but are generally broken and are made up of a succession of well rounded peaks. These peaks are always completely covered with trees and from the top of the sharpest of them it is impossible to get a view of the surrounding country. The highest point climbed was about 2,000 feet above sea level and the highest peak in Darien is Mt. Pyrrhi which is between three and four thousand.

Darien has been the scene of a great deal of surveying and exploration from the time that Columbus, in 1503, coasted along its shores, hoping to find a strait connecting the two oceans, up to the present time. Balboa, in 1510, discovered the Pacific by crossing the Darien mountains from Caledonia Bay. This discovery taken in connection with the broad indentations of the land noted by Columbus, led the old world to believe in the existence of a strait, and the entire coast on each side of the new world was diligently searched. The Cabots, Ponce de Leon and Cortez interested themselves in this search and it was not until about 1532 that all expectations of finding the strait were abandoned. The idea of a direct natural communication between the oceans being thus dispelled, the question of an artificial junction arose, and in 1551 a Spanish historian recommended to Philip II. of Spain the desirability of an attempt to join the oceans by identically the same routes to which the attention of the whole civilized portion of the world is now being drawn, that is, Tehauntepec, Nicaragua and Panama. From this time up to the commencement of the work of the Isthmian expeditions sent out by the United States, and which lasted from 1870 to 1875, but little geographical knowledge relative to Darien was obtained. The United States expeditions undoubtedly did a great amount of valuable exploration and surveying, and while the names of Strain, Truxton, Selfridge and Lull will always be held in high esteem for what they accomplished in this direction, still it is to be regretted that with all the resources at their command they did not make a complete map of the country. And just here I want to bring forward the suggestion that all that has been accomplished and more, could have been accomplished if the various explorers had known, or practically utilized, a fact that my own experience and that of other topographers, in this country and Darien, has impressed upon me; and that is, that it is easier in a rough and mountainous country to travel on the ridge than in the valley. In Darien they were looking for a low pass in the Cordillera and this was what should have first been sought, directly. Having found the low passes the valleys of the streams draining therefrom could have then been examined, and thus all necessary information could have been obtained and the subject exhausted. The plan followed by the Isthmian expeditions was to ascend a stream with the hope of finding a suitable pass. The pass might be found or it might not, and if not, so much labor as far as the direct solution of the problem was concerned was lost. A pass of low altitude was of primary importance and should have been sought for in an exhaustive way.

Humboldt said in substance, "Do not waste your time in running experimental lines across. Send out a party fully equipped, which keeping down the dividing ridge the whole length of the Isthmus, by this means can obtain a complete knowledge of the hypsometrical and geological conditions of the dam that obstructs the travel and commerce of the world." But strange to say this plan suggested by such an eminent authority as Humboldt and so strongly recommended by common sense, has never been followed, and to-day after all the money that has been spent and the lives lost in explorations in Darien, there is not sufficient data collected to prove conclusively that there does not now exist some route for an interoceanic canal that possesses merits superior to any at present known. It is true the dividing ridge would be difficult to follow on account of the great number of confusing spurs, but I think I am safe in saying that starting from the summit of the main ridge at Culebra pass on the Isthmus of Panama, the dividing ridge extending to the pass at the head waters of the Atrato could be exhaustively followed and studied with as much facility as could either the Tuyra or Atrato rivers, embracing with each their respective tributaries.

I traveled on some of the high dividing ridges in Darien, and did not find that progress was at all difficult, and especially noted the fact of the absence of tangled undergrowth and matted vines which is so characteristic of the Darien forests generally.

Now a few words about the inhabitants of Panama and Darien, and in referring to these I mean the native inhabitants and not the indiscriminate gathering of all nationalities that were attracted by the Panama Canal.

In Central and South America, as in North America, the aboriginal inhabitant was the Indian. When the Spaniards first attempted to colonize Darien they were met and resisted by the native Indian just as our forefathers were in Virginia and Massachusetts, and as with us so in Panama and Darien the Indians have been driven back by degrees from the shores of both oceans until now they are found only in the far interior.

They resemble our Indians in appearance, but are smaller. They are averse to manual labor and live almost entirely by hunting and fishing, although they sometimes have small plantations of plantains, bananas, oranges and lemons. The Spaniards in settling in the new country brought very few women with them and the Colombian of to-day is the result of the admixture of the Indian and Spanish blood, and has many of the characteristics of each race. In addition to the Indian and Colombian there are in Panama and Darien a comparatively large number of negroes, who were originally imported as slaves by the early Spaniards, and who now constitute by far the larger portion of the inhabitants of Darien, being found usually in villages along the valleys of the larger streams. In contrast to the Colombian and Indian they are large in stature and make excellent laborers.

The principal villages in Darien, as Yovisa, Pinagana and Real de St. Marie, are inhabited exclusively by the negroes, with the exception of a Spanish judge in each, who exercises great authority. Besides being a judge in civil and criminal cases, he practically controls everything in his particular village, as all contracts for labor are negotiated with him and settlement for services made through him.

Upon reaching Darien the first work assigned me was the survey and exploration of the Pyrrhi river. This survey was made for two purposes: primarily, to determine if any of the country bordering upon it was of a sufficiently desirable character to include it within the grant, and secondly, to secure data for the general topographical map. My instructions were to proceed as far south as latitude 7°·30′. The ascent of the river was made in canoes until the frequency of rapids made it necessary to abandon them, and then the journey was continued on foot, generally wading in the middle of the stream, as the undergrowth was too thick to admit of progress along the banks. Sometimes the water was very shallow; at other times, where it had been backed up by dams of porphyritic rock, it reached above the waist, and near the end of the journey where the river ran between vertical walls of great height it was necessary to swim in order to get beyond this cañon.

The survey of this river was satisfactorily accomplished in about a week. The method adopted for the survey was to take compass bearings and to estimate distances. These courses and distances were plotted as they were taken and thus the topographical and other features could be readily sketched in connection with them. To check and control this work, observations were taken every day at noon with a sextant, on the sun, for latitude and time, and at night circum-meridian altitudes of stars were obtained when possible.

Thus a number of rivers were surveyed—the Maria, Tucuti, Yovisa and other tributaries of the Tuyra. When it was found that a sufficiently correct idea of the country for topographical purposes could not be obtained by simply meandering the water courses, lines or *trochas* were cut through the forest from stream to stream, and where two streams thus connected were tributaries of a common river, all of which had been previously surveyed, a closed figure was obtained, an adjustment for errors of closure made, and by putting together the topographical data obtained by the four lines, there was generally found to be sufficient information to give a satisfactory though of course a crude delineation of the included area.

After a number of rivers had been examined with more or less accuracy in this way, it was finally decided that the area for one portion of the grant best suited for the purposes of the Canal Company lay on the right bank of the Tuyra river, and that the portion of the river which lay between the mouths of two of its tributaries, the Rio Yape and the Rio Pucro, should be one of the boundaries of the grant. The Yape and Pucro have courses approximately parallel to each other and at right angles to the Rio Tuyra, and these streams were also chosen as boundary lines, so that the grant would have the three rivers as natural boundaries, and the fourth and closing boundary was to be a straight line from a certain point on the Yape to the Pucro, so located as to include within the four boundaries an area approximately equal to the amount of the grant, which in this particular case was 25,000 hectares. The problem then presented was: given three rivers for three boundaries of a figure to establish a fourth and artificial line, completing the figure in such a way that it should contain a given area, and also to procure data for a topographical map of the country surveyed.

This survey was put under my direction and I was instructed to proceed to a point overlooking the Tuyra river, between the Rio Yape and the Rio Pucro, near the mouth of the Rio Capite, for the purpose of establishing a base camp. Leaving Real de St. Marie on the evening of March 15th, with a fleet of twelve canoes and about thirty native laborers, we reached the site for the camp in two days. After landing everything, the work of clearing away trees and underbrush over an area sufficiently large for the camp was commenced. The men worked willingly with axe and machéte, and soon the forest receded and left bare a semi-circular space facing the river.

Two houses were needed and without saw, nail or hammer the construction was commenced and prosecuted rapidly. Straight trees about six inches in diameter and twenty feet long were cut and planted vertically in holes dug out with the machéte, and horizontal pieces of a smaller diameter were securely fastened on with long tough strips of bark, and thus a square or oblong frame was fashioned. The horizontal pieces were placed at a distance of about three feet from the ground, on which a flooring was eventually laid, and at the top of the frame where the slope of the roof began. On the top pieces other poles were laid and fastened across and lengthwise, and on these the men stood while making the skeleton of the roof. The latter was made very steep for better protection against the rain. After the ridge pole was put in position other smaller poles were fastened on parallel and perpendicular to it so that the whole roof was divided up into squares, and it was finally completed by weaving in thick bunches of palm and other leaves in such a way as to make it thoroughly water-proof. For our purpose no protection on the sides of the structures other than the projecting eaves was considered necessary. A floor of poles laid very close together was put in one house, the one used for sleeping purposes, and in the other a table for eating, writing, draughting, etc., was made. Thus in two or three days the place was made thoroughly habitable, and men were detailed to see that the grounds, etc., were always kept thoroughly clean and in a good sanitary condition, a very necessary precaution in a tropical country. The forest afforded game, the river an abundance of fish; bananas, oranges, lemons and pineapples were easily procured from the natives, who also furnished material for a poultry yard, and thus while located at camp Capite, situated as it was on a picturesque spot overlooking two swiftly flowing rivers, with good drinking water, a commissary department well stocked, a French cook who would have done himself credit anywhere, I could not but think that heretofore pictures of life in Darien had been too somberly drawn, and that where so much suffering and sickness had prevailed among the early explorers it was because they had gone there not properly outfitted, and because carried away with ambitious enthusiasm their adventurous spirit had caused them often to undertake that which their calmer judgment would not have dictated; and that to these causes as much as to the unhealthy condition of the locality was due their many hardships. Several days were spent here getting time and latitude observations and in mapping out plans for the work. It was decided that the mouths of the Yape, Capite and Pucro and other points along these rivers, such as mouths of tributary streams, etc., should be astronomically located, that these points should be connected by compass lines, and also that cross lines should be run at various points from the Yape to the Capite and from the Capite to the Pucro. It was further decided that as time was limited it would be impracticable to run out the fourth side of the figure that would contain the grant, as the country around the headwaters of the streams was known to be exceedingly rough and mountainous, and to follow any straight line would necessarily involve a great amount of laborious cutting and climbing.

Furthermore, in order to know just what direction this line should follow it would be first necessary to make a connected preliminary survey of the three rivers ; to plot this survey and then by inspection of the map and consideration of various starting points to decide on the most available location of the fourth side.

Instead of this it was considered best and sufficient to arbitrarily adopt a certain waterfall on the Rio Yape, the location of which was approximately known from a reconnoisance previously made, as the initial point of the line connecting the upper Yape with the Pucro and closing the figure. Thus it only became necessary, as far as the boundaries were concerned, to run a line along the Tuyra, joining the mouths of the Yape and Pucro ; to run a line from the mouth of the Yape to the waterfall above referred to ; and to run up the Pucro sufficiently far to be certain that when the work was completed and plotted, a line drawn from the position of the waterfall on the map in such a way as to include the desired area would intersect the Pucro at some point within the limit of what had been surveyed. I have not time to go into the details of the various trips by land and water necessary to carry out these plans.

Before starting it was known exactly what was necessary to be done ; each assistant engineer had his work clearly mapped out before him, and each one faithfully performed the task allotted to him, so that the whole survey was brought to a successful completion. This brought to a close all the work in Darien, the other tracts having been surveyed before my arrival and consequently the whole expedition returned to Panama, and soon afterwards I returned to this country.

In going to and returning from Darien, I passed twice over the Panama railroad and along the line of the Panama canal, and I have thought that a few facts relative to the canal and railroad might prove of interest to the Geographical Society.

Published herewith is a sketch showing the location of the railroad, canal and tributary drainage, and a profile along the axis of the canal.

The first surveys for the railroad were made in 1849, and it was probably the excitement of the California gold fever that brought about its construction at this particular time. Ground was broken in January, 1850, and the last rail was laid in January, 1855.

The length of the road is 47.6 miles and it crosses the dividing summit at an elevation of 263 feet above the mean level of the Atlantic ocean. The maximum grade is 60 feet to the mile. Soon after the road was built accurate levels were run to determine the difference, if any, between the Atlantic and Pacific oceans, and it was found that the mean levels were about the same, although there are of course variations owing to local causes, and considerable differences of height at times, owing to differences of tides in the Atlantic and Pacific. At Aspinwall the greatest rise is only 1.6 feet, while at Panama there is at times a difference of over 21 feet between high and low water. The cost of the railroad was $75,000,000.

The existence of the railroad was probably the deciding cause that led Lesseps to the adoption of this location of the proposed canal.

Now that the scheme has practically failed it is very easy to see and appreciate the difficulties that lay in the way of building a canal at this particular place; and it certainly seems that if sound engineering principles had been adopted at least some of these difficulties could have been understood and properly combatted. The whole scheme, however, from an engineering standpoint, seems to have been conducted in the most blundering manner.

Lesseps is a diplomat and financier, but in no sense a great engineer. In the construction of the Suez canal, the questions of diplomacy and finance were the most difficult to settle, while the engineering problems were comparatively simple. In Panama the opposite conditions prevailed. Concessions were freely given him by the Colombian government and money freely offered him by the French people, but he never grasped or comprehended the difficulties that nature had planted in his way, and these only seemed to occur to him when they blocked progress in a certain direction. The Paris Conference, controlled by Lesseps, decided on the 29th of May, 1879, that the construction of an inter-oceanic canal was possible and that it should be built from the Gulf of Limon to the Bay of Panama.

The tide-level scheme was adopted and the following dimensions decided upon, viz : Length, 45.5 miles ; depth, 28 feet ; width at water line 164 feet, and width at bottom 72 feet.

The route determined upon was about the same as that of the railroad, that is along the valleys of the Chagres and Obispo, crossing the divide at the Culebra pass and then descending to the Pacific along the course of the Rio Grande. The profile which is reproduced from "Science," shows the state of progress on January 1st, 1888, and the amount of excavation that has been done since that time would make but a slight difference in the appearance of the profile. The portion shown in black is what has been removed along the axis of the canal and represents an expenditure of over $385,000,000 and seven years' labor. The reasons that make the scheme impracticable are briefly these, some of which were known before the work was commenced, and all of which should have been understood.

The first great difficulty is in cutting through the ridge culminating at Culebra where the original surface was 354 feet above the bed of the proposed canal. It was never known what the geological formation of this ridge was until the different strata were laid bare by the workman's pick, and the slope adopted, $1\frac{1}{2}$ to 1, was found to be insufficient in the less compact formations, even at the comparatively shallow depth that was reached, and many and serious landslides were of frequent occurrence.

Another serious difficulty was the disposition of the excavated material, for upon the completion of a sea-level course this channel would naturally drain all the country hitherto tributary to the Chagres and Rio Grande, and any substance not removed to a great distance would eventually be washed back again into the canal. But perhaps the greatest difficulty was in the control of the immense surface drainage. The Chagres river during the dry season is, where it crosses the line of the canal near Gamboa, only about two feet deep and 250 feet wide, but during a flood the depth becomes as much as forty feet, the width 1,500 feet, and the volume of water discharged 160,000 cubic feet per second. The bed of the river is here 42 feet above sea level, or 70 feet above what the bottom of canal would have been. Now add to this a 40-foot flood and we have a water surface one hundred and ten feet above the bed of the canal.

In order to keep this immense volume of water from the canal it was proposed to build a large dam at Gamboa, and to convey the water by an entirely different and artificial route to the Atlantic. It is impossible to show on the map the whole drainage area of the Chagres, but a rough calculation shows it to be about 500 square miles. This seems a small total drainage area, but when it is considered that the annual rainfall is about 12 FEET, that this rainfall is confined to about one half the year, and that in six consecutive hours there has been a precipitation of over six inches of rain, some idea of the amount of water that finds its way through the Chagres river during the wet season may be formed.

As I said before it was proposed to protect the canal from the waters of the upper Chagres by an immense dam at Gamboa, and for the purpose of controlling the water tributary to the lower Chagres two additional canals or channels were to be constructed on either side of the main canal. Thus, as the river is very tortuous and the axis of the canal crossed it twenty-five or thirty times, many deviations of the former became necessary. In some places the canal was to occupy the bed of the river and in others it cut across bends leaving the river for its original natural purpose of drainage. The difficulty in retaining the floods in these constructed channels would of course be immense, especially in some of the cases where the water rushing along its natural channel is suddenly turned at right angles into an artificial one. Thus it is clear that aside from the enormous expense incident to the removal of the immense amount of earth and rock necessary to complete the canal, that granting all this accomplished, it would be practically impossible to maintain a sea-level canal by reason of the difficulty in controlling the Chagres and preventing the canal from filling up.

The canal company finally came to the conclusion that the sea-level scheme was impracticable and it was abandoned, and plans were prepared for a lock system. As seen on the profile there were ten locks proposed, five on each side of the summit level. The summit level was to be 150 feet above sea level and consequently each lock would have a lift of thirty feet. The profile was constructed especially to show the amount remaining to be executed to complete the lock system, and a mere inspection will show the relative amount of completed and uncompleted area along the axis of the canal. To complete the summit cut it is still necessary to excavate 111 feet, 93 feet having already been excavated, through a horizontal distance of 3300 feet. The width of cut at top surface for the required depth at a slope of $1\frac{1}{2}$ to 1 would be 750 feet, but as I said before, at this slope landslides were of frequent occurrence and the slope would probably have to be increased to at least 2 to 1.

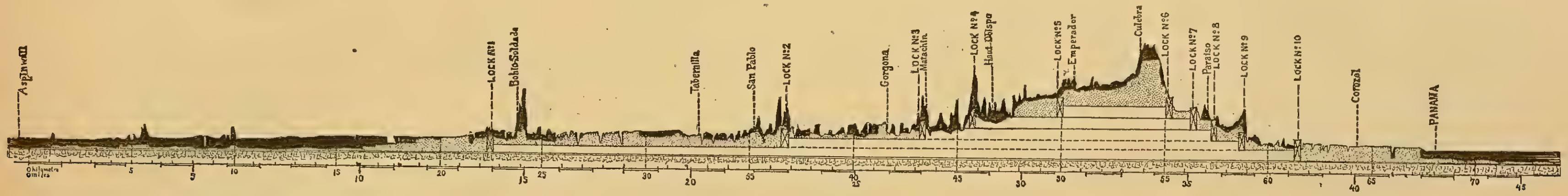
Granting the necessary excavations made, there would be still the problem of the control of the Chagres river and the water supply for the summit level to provide for. At first it was thought that the water supply could be obtained from the storage of the waters of the Chagres and Obispo, but this idea was eventually abandoned, either from a belief in the insufficiency of the water supply during the dry season, or from difficulties in the way of conveying the water to the summit level.

Then it was that the advice of Mr. Eiffel, a noted French engineer, was sought, and after a visit to the Isthmus he proposed that the summit level should be supplied by pumping from the Pacific. A contract was immediately made with Eiffel, who was heralded all over the world as the man who would save the canal, and immediately a positive day, the seventh that had been announced, was fixed for the opening of the great canal.

I do not know just how much work was done towards perfecting the system for pumping, but probably very little was ever accomplished in this direction, as soon after this scheme was thought of the available funds of the canal company began to be very scarce, and there has been since then a general collapse of work all along the line until now it is entirely suspended. From what I have said and from what can be seen from the profile, it will be readily understood that as far as the sea-level project is concerned the amount done is not much more than a scraping of the surface, relatively speaking, and that what has been done is in places where the obstacles were fewest.

In regard to the lock canal about one third of the necessary excavation has been made along the axis of the canal, but taking into consideration other requirements necessary for the completion of the scheme, I should estimate, roughly, that probably only one sixth of the whole amount of work had been accomplished. The question now naturally arises as to what will be the probable future of this great enterprise.

The French people have seen the scheme fail under Lesseps in whom they had the most unbounded confidence, and it is not likely that they will raise any more money to be put in it as a business enterprise under any other management. Saddled as it is with a debt of nearly four hundred millions of dollars, it would be difficult to convince any one that it could ever prove to be a paying investment. Nor do I think that any American or English corporation can be organized that could obtain such concessions from Lesseps as would make the scheme an inviting field for capitalists, and thus my opinion is that the "*Compagnie Universelle du Canal Interocéanique de Panama* has irretrievably collapsed, and that the canal will remain, as it is now, the most gigantic failure of the age.



PROFILE OF THE PANAMA CANAL.

Black indicates work executed; stipple, work to be executed to complete a lock-canal; white, additional work to be executed to complete a sea-level canal.


Julius Bien & Co.

ENTRANCE TO HIGHLANDS _ RIVER SAN JUAN


Pueblo N
Naga

Ayre

THE NICARAGUA CANAL

Julius Bien & Co.

ACROSS NICARAGUA WITH TRANSIT AND MACHÉTE.

BY R. E. PEARY.

THE action of this National Society, with its array of distinguished members, in turning its attention for an hour to a region which has interested the thinking world for more than three centuries gives me peculiar pleasure and satisfaction.

I propose this evening to touch lightly and briefly upon the natural features of Nicaragua, to note the reasons for the interest which has always centered upon her, to trace the growth of the great project with which her name is inseparably linked; to show you somewhat in detail, the life, work, and surroundings of an engineer within her borders; and finally to show you the result that is to crown the engineer's work in her wide spreading forests and fertile valleys.

That portion of Central America now included within the boundaries of our sister republic Nicaragua, has almost from the moment that European eyes looked upon it attracted and charmed the attention of explorers, geographers, great rulers, students, and men of sagacious and far reaching intellect.

From Gomara the long list of famous names which have linked themselves with Nicaragua reaches down through Humboldt, Napoleon III, Ammen, Lull, Menocal and Taylor.

The shores were first seen by Europeans in 1502, when Columbus in his fourth voyage rounded the cape which forms the northeast angle of the state, and called it "Gracias á Dios," which name it bears to-day. Columbus then coasted southward along the eastern shore.

In 1522, Avila, penetrated from the Pacific coast of the country to the lakes and the cities of the Indian inhabitants. Previous to this the country was occupied by a numerous population of Aztecs, or nearly allied people, as the quantities of specimens of pottery, gold images, and other articles found upon the islands and along the shores of the lakes, prove conclusively.

In 1529 the connection of the lakes with the Caribbean sea was discovered, and during the last half of the eighteenth century a considerable commerce was carried on by this route between Granada on Lake Nicaragua and the cities of Nombre de Dios, Cartagena, Havana and Cadiz.

In 1821 Nicaragua threw off the rule of the mother country and in 1823 formed with her sister Spanish colonies, a confederation. This confederation was dissolved in 1838, and since then Nicaragua has conducted her own affairs. In point of advancement, financial solidity and stability of government she stands to-day nearly, if not quite, at the head of the Central American republics.

Nicaragua extends over a little more than four degrees each of latitude and longitude, from about N. 11° to N. 15° and from 83° 20′ W. to 87° 40′ W.

Its longest side is the northern border from the Gulf of Fonseca northeasterly to Cape Gracias á Dios, two hundred and ninety miles. From that cape south to the mouth of the Rio San Juan, the Caribbean coast line, is two hundred and fifty miles. Nearly due west across the Isthmus to Salinas Bay on the Pacific, is one hundred and twenty miles. The Pacific coast line extends thence northwest one hundred and sixty miles.

In point of size Nicaragua stands first among the Central American republics having an area of 51,600 square miles. It is larger than either the State of New York or Pennsylvania, about the size of Denmark, Belgium, the Netherlands and Switzerland combined, and is one-fourth as large as France or Germany. Its population numbers about 300,000.

The Gulf of Fonseca, at the northern, and Salinas Bay at the southern extremity of the coast line are two of the finest and largest harbors on the Pacific coast of Central America. About midway between them is the fine harbor of Corinto, and there are also several other ports along the coast, at San Juan del Sur, Brito and Tamarindito. On the Caribbean coast no harbors suitable for large vessels exist, but numerous lagoons and bights afford the best of shelter for coasting vessels.

The central portion of Nicaragua is traversed, from north to south, by the main *cordillera* of the isthmus, which, here greatly reduced in altitude, consists merely of a confused mass of peaks and ridges with an average elevation scarcely exceeding 1,000 feet.

Between this mountainous region and the Caribbean shore stretches a low level country, covered with a dense forest, rich in rubber, cedar, mahogany and dye woods. It is drained by several large rivers whose fertile intervales will yield almost incredible harvests of plantains, bananas, oranges, limes, and other tropical fruits.

West of the mountain zone is a broad valley, about one hundred and twenty-five feet above the level of the sea, extending from the Gulf of Fonseca, southeasterly to the frontier of Costa Rica. The greater portion of this valley is occupied by two lakes, Managua and Nicaragua. The latter one hundred and ten miles long by fifty or sixty miles wide is really an inland sea, being one-half as large as Lake Ontario and twice as large as Long Island Sound. These lakes, with the rainfall of the adjacent valleys, drain through the noble San Juan river, which discharges into the Caribbean at Greytown, at the southeast angle of the country.

Between the Pacific and these lakes is a narrow strip of land, from twelve to thirty miles in width, stretching from the magnificent plain of Leon with its cathedral city, in the north, to the rolling indigo fields and the cacao plantations which surround the garden city of Rivas, in the south.

The lowest pass across the backbone of the New World, from Behring's Strait to the Straits of Magellan, extends along the San Juan valley and across the Lajas—Rio Grande "divide," between Lake Nicaragua and the Pacific; the summit of this divide is only one hundred and fifty-two feet above the sea and forty-two feet above the lake.

Nicaragua presents yet another unique physical feature. Lying between the elevated mountain masses of Costa Rica on the south and Honduras on the north, the average elevation of its own mountain backbone hardly one thousand feet, it is the natural thoroughfare of the beneficent northeast Trades. These winds sweep in from the Caribbean across the Atlantic slopes, break the surface of the lakes into sparkling waves, and then disappear over the Pacific, aerating, cooling and purifying the country, destroying the germs of disease and making Nicaragua the healthiest region in Central America.

The scenery of the eastern portion of the country is of the luxuriant sameness peculiar to all tropical countries.

In the vicinity of the lakes and between them and the Pacific, the isolated mountain peaks which bound the plain of Leon on the northeast; the mountain islands of Madera and Ometepe; the towering turquoise masses of the Costa Rican volcanoes; and the distant blue mountains of Segovia and Matagalpa, visible beyond the sparkling waters of the lakes, feast the eye with scenic beauties, unsurpassed elsewhere in grandeur, variety and richness of coloring.

The products of the country are numerous despite the fact that its resources are as yet almost entirely undeveloped.

Maize, plantains, bananas, oranges, limes, and indeed every tropical fruit, thrive in abundance. Coffee is grown in large quantities in the hilly region in the northwest; sugar, tobacco, cotton, rice, indigo and cacao plantations abound between the lakes and the Pacific; potatoes and wheat thrive in the uplands of Segovia; the Chontales region east of Lake Nicaragua, a great grazing section, supports thousands of head of cattle; and back of this are the gold and silver districts of La Libertad, Javali and others.

Numerous trees and plants of medicinal and commercial value are found in the forests. Game is plentiful and of numerous varieties; deer, wild hog, wild turkey, manatee and tapir; and fish abound in the streams and rivers. The temperature of Nicaragua is equable. The extreme variation, recorded by Childs, was 23° observed near the head of the San Juan in May, 1851.

The southeast wind predominates during the rainy season. Occasionally, in June or October as a rule, the wind hauls round to southwest and a *temporal* results, heavy rain sometimes falling for a week or ten days.

The equatorial cloud-belt, following the sun north in the spring, is late reaching Nicaragua, and the wet season is shorter than in regions farther south. The average rainfall, based on the records of nine years, is 64.42 inches. The "trades" blow almost throughout the year. Strong during the dry season and freshening during the day; the wind comes from the east-northeast, and blows usually for four to five days, when, hauling to the east or southeast for a day or two, it calms down, then goes back to northeast and rises again.

The Spanish discoverers of the great Lake Nicaragua, coming upon it from the Pacific, and noting the fluctuations of level caused

LEON CATHEDRAL

by the action of the wind upon its broad surface, mistook these fluctuations for tides and felt assured that some broad strait connected it with the North Sea. Later, when Machuca had discovered the grand river outlet of the lake, and the restless searching of other explorers in every bay and inlet along both sides of the American isthmus had extinguished forever the ignis fatuus "Secret of the Strait," Gomara pointed this out as one of the most favorable localities for an artificial communication between the North and South Seas.

It was not until 1851, however, that an accurate and scientific survey of a ship canal route was made by Col. O. W. Childs.

This survey which showed the lake of Nicaragua to be only one hundred and seven feet above the sea, and the maximum elevation between the lake and the Pacific to be only forty-one feet, exhibited the advantages of this route so clearly and in such an unanswerable manner that it has never since been possible to ignore it.

In 1870, under the administration of General Grant and largely through the unceasing efforts of Admiral Ammen, the United States began a series of systematic surveys of all the routes across the American isthmus from Tehuantepec to the head waters of the Rio Atrato ; and six years later, with the plans and results of all these surveys before it, a commission composed of General Humphreys, Chief of Engineers, U. S. Army ; Hon. Carlile Patterson, Superintendent U. S. Coast Survey ; and Rear-Admiral Daniel Ammen, Chief of Bureau of Navigation, U. S. Navy ; gave its verdict in favor of the Nicaragua route.

The International Canal Congress at Paris, in 1879, had such convincing information placed before it that it was forced, in spite of its prejudices, to admit that in the advantages it offered for the construction of a lock canal, the Nicaragua route was superior to any other across the American isthmus.

In 1876, and again in 1880 Civil Engineer A. G. Menocal, U. S. N., the chief engineer of previous governmental surveys, resurveyed and revised portions of the route, and in 1885 the same engineer, assisted by myself, surveyed an entirely new line on the Caribbean side, from Greytown to the San Juan river, near the mouth of the San Carlos.

On the eastern side of Nicaragua, all these surveys (except the last), were confined almost entirely to the San Juan river, and its immediate banks ; and the country on either side beyond these narrow limits was, up to 1885, almost entirely unknown. Between Lake Nicaragua and the Pacific, however, every pass from the Bay of Salinas to the Gulf of Fonseca had been examined.

In 1885 the party of which I was a member pushed a nearly direct line across the country from a point on the San Juan, about three miles below the mouth of the Rio San Carlos, to Greytown, a distance of thirty one miles by our line, as compared with fifty-six miles by the river and forty-two miles by the former proposed canal route.

In December, 1887, I went out in charge of a final surveying expedition, consisting of some forty engineers and assistants and one hundred and fifty laborers, to resurvey and stake out the line of the canal preparatory to the work of construction.

The information and personal experience gained in previous surveys made it possible, without loss of time, to locate the various sections of the expedition in the most advantageous manner, and push the work with the greatest speed consistent with accuracy.

The location lines of the previous surveys were taken as a preliminary line and carefully re-measured and re-levelled. Preliminary offsets were run; the location made, and staked off upon the ground; offsets run in from three hundred to one hundred feet apart, extending beyond the slope limits of the canal; borings made at frequent intervals; and all streams gauged.

The result of this work was a series of detail charts and profiles, based upon rigidly checked instrumental data, and covering the entire line from Greytown to Brito, from which to estimate quantities and cost.

As may be imagined by those familiar with tropical countries, the prosecution of a survey in these regions is an arduous and difficult work, and one demanding special qualifications in the engineer. His days are filled with a succession of surprises, usually disagreeable, and constant happenings of the unexpected. Probably in no other country will the traveler, explorer, or engineer, find such an endless variety of obstacles to his progress.

Every topographical feature of the country is shrouded and hidden under a tropical growth of huge trees and tangled underbrush, so dense that it is impossible for even a strong, active man, burdened with nothing but a rifle, to force himself through it without a short, heavy sword or *machête*, with which to cut his way.

Under these circumstances the most observant engineer and expert woodsman may pass within a hundred feet of the base of a considerable hill and not have a suspicion of its existence, or he may be entirely unaware of the proximity of a stream until he is on the point of stepping over the edge of its precipitous banks.

The topography of the country has to be laboriously felt out, much as a blind man familiarizes himself with his surroundings. In doing this work the indispensable instrument, without which the transit, the level, and indeed the engineer himself is of no use, is the national weapon of Nicaragua, the *machéte*, a short, heavy sword.

As soon as he is able to walk, the son of the Nicaraguan *mozo* or *hulêro* takes as a plaything a piece of iron hoop or an old knife, and imitates his father with his *machéte.* As he gets older a broken or worn-down weapon is given him, and when he is able to handle it, a full size *machête* is entrusted to him and he then considers himself a man. From that day on, waking or sleeping, our Nicaraguan's *machête* is always at his side. With it he cuts his way through the woods ; with it he builds his camp and his bed ; with it he kills his game and fish ; with it at a pinch he shaves himself, or extracts the thorns from his feet ; with it he fights his duels, and with it, when he dies, his comrades dig his grave.

When in the field the chief of a party, equipped with a pocket compass and an aneroid barometer, is always skirmishing ahead of the line with a *machêtero*, or axeman, to cut a path for him. A pushing chief, however, speedily dispenses with the *machêtero* and slashes a way for himself much more rapidly.

As soon as he decides where the line is to go the engineer calls to the *machêteros* and the two best ones immediately begin cutting toward the sound of his voice. They soon slash a narrow path to him, drive a stake where he was standing and then turn back toward the other *machêteros,* who have been following them, cutting a wider path and clearing away all trees, vines and branches, so that the transit man can see the flag at the stake. The moment the leading *machêteros* reach him the chief starts off again and by the time the main body of axemen have reached his former position the head *machêteros* are cutting toward the sound of his voice in a new position.

As soon as the line is cleared the transit man takes his sight and moves ahead to the stake, the chainmen follow and drive stakes every hundred feet, and the leveller follows putting in elevations and cross sections. In this way the work goes on from early morning until nearly dark, stopping about an hour for lunch.

After the day's work comes the dinner, the table graced with wild hog, or turkey, or venison, or all. After dinner the smoke, then the day's notes are worked up and duplicated and all hands get into their nets. For a moment the countless nocturnal noises of the great forest, enlivened perhaps by the scream of a tiger, or the deep, muffled roar of a puma, fall upon drowsy ears, then follows the sleep that always accompanies hard work and good health, till the bull-voiced howling monkeys set the forest echoing with their announcement of the breaking dawn.

In reconnoissance and preliminary work the experienced engineer, is able, in many cases, to avoid obstacles without vitiating the results of his work, but in the final location, in staking out absolute curves and driving tangents thousands of feet long across country, no dodging is possible.

On the hills and elevated ground the engineer can, comparatively speaking, get along quite comfortably, his principal annoyances being the uneven character of the ground, which compels him to set his instrument very frequently, and the necessity of felling some gigantic tree every now and then.

In the valleys and lowlands there is an unceasing round of obstacles. The line may run for some distance over level ground covered with a comparatively open growth, then without warning it encounters the wreck of a fallen tree, and hours are consumed hewing a passage through the mass of broken limbs and shattered trunk, all matted and bound together with vines and shrubbery. A little farther on a stream is crossed, and the line may cross and recross four or five times in the next thousand feet. The engineer must either climb down the steep banks, for the streams burrow deep in the stiff clay of these valleys, ford the stream and climb the opposite bank, or he must fall a tree from bank to bank and cross on its slippery trunk twenty or twenty-five feet above the water.

Either on the immediate bank or in its vicinity is almost certain to be encountered a "*saccate*" clearing. This may be only one or two hundred feet across or it may be a half a mile. In the former case the "*saccate*" grass will be ten or fifteen feet in height and so matted and interwoven with vines and briars that a tunnel may be cut through it as through a hedge. If the clearing be large, the tough, wiry grass is no higher than a man's head, and a path has to be mowed through it, while the sun beats down into the furnace-like enclosure till the blade of the *machête* becomes almost too hot to touch.

But worse than anything thus far mentioned are the *Silico* or black palm swamps. Some of these in the larger valleys and near the coast are miles in extent.

Occupied exclusively by the low, thick *Silico* palms, these swamps are in the wet season absolutely impassable except for monkeys and alligators, and even at the end of the dry season the engineer enters upon one with sinking heart as well as feet, and emerges from it tired and used up in every portion of his anatomy. It is with the utmost difficulty that he finds a practicable place to locate his instrument, generally utilizing the little hummocks formed by the trunks of the clusters of palms, and in moving from point to point he is compelled to wade from knee to shoulder deep in the black mud and water.

General reconnaissances from high trees in elevated localities, simple enough in theory, are by no means easy in a country so miserly with its secrets as this, nor are their results reliable without a great expenditure of time, labor, and patience.

On level, undulating and moderately broken ground, the tops of the trees, though they may be one hundred and fifty feet from the ground, are level as the top of a hedge. Even an isolated hill if it be rounded in shape presents hardly better facilities, the trees at the base and on the sides, in their effort to reach the sunlight grow taller than those on the summit, and there is no one tree that commands all the others.

If however an isolated hill of several hundred feet in height be found, its steep sides culminating in a sharp peak, one day's work by three or four good axmen, in cutting neighboring trees, will prepare the way for a study of the general relief and topography of the adjacent country. If after these preliminaries have been completed the engineer imagines that he has only to climb the tree and sketch what he sees, to obtain reliable knowledge of the country, he is doomed to serious surprises in the future. If he makes the ascent during the middle of the day, he will, after he has cooled off and rested from his exhausting efforts, see spread out before him a shimmering landscape in which the uniform green carpet and the vertical sun combined, have obliterated all outlines except the more prominent irregularities of the terrene, and have blended different mountain ranges, one of which may be several miles beyond the other, into one, of which only the sky profile is distinct. Naturally under these conditions estimates of distance may be half or double the truth.

There are two ways of extracting reliable information from these tree-top reconnaissances. If it be in the rainy season the observer must be prepared to make a day of it, and when he ascends the tree in the morning he takes with him a long light line with which to pull up his coffee and lunch.

Then aided by the successive showers which sweep across the landscape, leaving fragments of mists in the ravines, and hanging grey screens between the different ranges and mountains, bringing out the relief first of this and then of that section, an accurate sketch may gradually be made. The time of passage of a shower from one peak to another, or to the observer, may also be utilized as a by no means to be despised check upon distance estimates.

If it be the dry season, the observer may take his choice between remaining on his perch in the tree from before sunrise to after sunset, or making two ascents, one early in the morning and the other late in the afternoon. In this case the slowly dispersing clouds of morning, and the gradually gathering mists at sunset, together with the reversed lights and shadows at dawn and sunset, bring out very clearly the relief of the terrene, the overlapping of distant ranges, and the course of the larger streams.

This kind of work cannot be delegated to anyone, and besides the arduous labor involved in climbing the huge trees, there are other serious annoyances connected with it. The climber is almost certain to disturb some venomous insect which revenges itself by a savage sting which has to be endured ; or he may rend clothes and skin also, on some thorny vine, or another, crushed by his efforts, may exude a juice which will leave him tattooed for days ; then, though there may not be a mosquito or fly at the base of the tree, the top will be infested with myriads of minute black flies, which cover hands and face, and with extremely annoying results. On the other hand the explorer may as a compensation have his nostrils filled with the perfume of some brilliant orchid on a neighboring branch ; and there is a breezy enjoyment in watching the showers as they rush across the green carpet, and in listening to the roar with which the big drops beat upon the tree tops.

The special phase of field work which fell to my personal lot was entirely reconnaissance, consisting of canoe examinations of all streams in the vicinity of the line of the canal, to determine their sources, character of valley, and approximate water shed ; of rapid air-line compass and aneroid trails, to connect one stream, or valley head with another, or furnish a base line for a general sketch plan of a valley ; and of studies of the larger features of the terrene, from elevated tree tops.

The last has been already described ; in the second the experience was very similar to that of the parties in running main lines. On these occasions three or at most four hardy *hulèros* (rubber hunters) comprised the party, two carrying the blankets, mosquito bars and provisions for several days, and one or two cutting the lightest possible practicable trail and marking prominent trees.

In a day's march of from five to eight miles, and this was the utmost that even such a light, active and experienced party could cover in one day, every possible and some almost impossible kinds of traveling was encountered, and thoroughly exhausted men crept into their bars every night.

The canoe reconnaissances were more agreeable, though some most unpleasant as well as most enjoyable memories are connected with them.

The innumerable large fallen trees which obstruct the streams and over or through which the canoe must be hauled bodily, the almost inevitable capsizing of the canoe, the monotonous red clay banks on either side and the frequent necessity of lying down at night in a bed of mud into which the droves of wild pigs which inhabit these valleys have trampled the clayey soil, are among the disagreeable incidents.

From the head of canoe navigation to their sources the character of these streams is entirely different, and both in 1888 and in 1885 I have followed them far up into mountain gorges, the beauty of which is as fresh in my memory as if I had been there but yesterday.

The crew of the canoe on these reconnaissances usually consisted of three picked men, and when the canoe had been pushed as far up stream as it was possible for it to go, two of the men were left with it while the third and best, slinging the blankets, bars, and a little coffee, sugar, and milk, upon his back pushed on with me. Wading through the shallow water up the bed of the stream, taking bearings and estimating distances, while my *hulèro* followed, ever alert to strike some drowsy beauty of a fish in the clear water; the source of the stream was generally reached in a day, and never did we make preparations to sleep on some bed of clean, yellow sand washed down by the stream in flood times, but what I had a plump turkey hanging from my belt, and my *hulēro* several fine fish.

Much has been written about the climate of Nicaragua and its effect upon the inhabitants of more northerly countries when exposed to it.

It would seem that the experience of the numerous expeditions sent out by the United States, and the reports of the surgeons attached to those expeditions would have long since settled the matter. To those who cannot understand how there can be such a difference in climate between two localities so slightly removed as Panama and Nicaragua, and the former possessing a notoriously deadly climate, the experience of the recent surveying expedition must be conclusive.

Only five members of that expedition had ever been in tropical climates before, and the rodmen and chainmen of the party were young men just out of college who had never done a day's manual labor, nor slept on the ground a night in their lives. Arriving at Greytown during the rainy season, the first work that they encountered was the transporting of their supplies and camp equipage to the sites of the various camps. This had to be done by means of canoes along streams obstructed with logs and fallen trees. Some parties were a week in reaching their destination, wading and swimming by day, lifting and pushing their canoes along, and at night lying down on the ground to sleep.

One party worked for six months in the swamps and lagoon region directly back of Greytown, and several other parties worked for an equal length of time in the equally disagreeable swamps of the valley of the San Francisco. Several of these officers are down there yet, as fresh as ever. In making tours of inspection of the different sections I have repeatedly, for several days and nights in succession, passed the days traveling in the woods through swamps and rain, and the nights sleeping as best I could, curled up under a blanket in a small canoe, while my men paddled from one camp to the next.

In spite of all this exposure not only were there no deaths in the expedition but there was not a single case of serious illness, and the officers who have returned up to this time, were in better health and weight than when they went away.

Julius Bien & Co.

UPPER CASTILLO _ RIVER SAN JUAN

Of course the men had the best of food that money could obtain and previous experience suggest, and the chiefs of all parties were required to strictly enforce certain sanitary regulations in regard to coffee in the morning, a thorough bath and dose of spirits on returning from work, and mosquito bars and dry sleeping suits at night; yet the climate must be held principally responsible for a sanitary result which I believe could not be excelled in any temperate zone city, with the same number of men, doing the same arduous work under conditions of equal exposure.

The forests everywhere abound in game and every party which included in its personnel a good rifle-shot was sure of a constant supply of wild pig, turkey, quail and grouse, varied by an occasional deer, all obtained in the ordinary work of reconnoissance and surveying. For the men's table there was abundance of monkey, iguana and macaw.

Parties in the lower valleys of the various streams had no trouble in adding two or three varieties of very toothsome fish to their bill of fare, though these fish were rarely caught with the hook, but usually shot, or knifed by an alert native, as they basked in the shallows. These parties also obtained occasionally a *danta* (tapir) or a manatee.

On the river it was possible to obtain a fine string of fish with hook and line, then there was the huge tarpon to be had for the spearing, and fish pots sunk in suitable places were sure to yield a mess of fresh water lobsters. Ducks were also occasionally shot.

The forms of life are even more numerous in the vegetable than in the animal kingdom. The effect of these wonderful forests is indescribable, and though many writers have essayed a description, I have yet to see one that does the subject justice. Only a simple enumeration of component parts will be attempted here. First comes the grand body of the forest, huge almendro, havilan, guachipilin, cortez, cedar, cottonwood, palo de leche trees, and others rising one hundred and fifty or two hundred feet into the scintillant sunshine. The entire foliage of these trees is at the top and their great trunks reaching up for a hundred feet or more without a branch offer a wonderful variety of studies in types of column. Some rise straight and smooth, and true, others send out thin deep buttresses, and others look like the muscle-knotted fore-arm of a Titan, with gnarled fingers griping the ground in their wide grasp.

But whatever the form of the tree trunks may be, the shallow soil upon the hills and the marshy soil in the lowlands, has taught them that there is greater safety and stability in a broad foundation than in a deeply penetrating one, and so almost without exception the tree roots spread out widely, on, or near, the surface. Beneath the protecting shelter of these patriarchs, as completely protected from scorching sun and rushing wind as if in a conservatory, grow innumerable varieties of palms, young trees destined some day to be giants themselves, and others which never attain great size. Still lower down, luxuriate smaller palms, tree ferns, and dense underbrush, and countless vines. These latter, however, are by no means confined to the underbrush, many of them climb to the very tops of the tallest trees, cling about their trunks and bind them to other trees and to the ground with the toughest of ropes. With one or two exceptions these vines are an unmitigated nuisance. To them more than to anything else is due the impenetrableness of the tropical thicket. Of all sizes and all as tough as hemp lines, they creep along the ground, catching the traveler's feet in a mesh from which release is possible only by cutting. They bind the underbrush together in a tough, elastic mat, which catches and holds on to every projection about the clothes, jerking revolvers from belts, and wrenching the rifle from the hand, or, hanging in trap-like loops from the trees, catch one about the neck, or constantly drag one's hat from the head. The one exception noted above is the *bejuco de agua* or water vine. This vine, which looks like an old worn manilla rope, is to be found hanging from or twined about almost every large tree upon elevated ground, and to the hot and thirsty explorer it furnishes a most deliciously cool and clear draught.

Seizing the vine in the left hand, a stroke of the *machête* severs it a foot or two below the hand, and another quick stroke severs it again above the hand ; immediately a stream of clear, tasteless water issues from the lower end and may be caught in a dipper or *á la native* directly in the mouth. A three-foot length of vine two inches in diameter will furnish at least a pint of water. The order of cutting mentioned above must invariably be adhered to, otherwise, if the upper cut be made first, the thirsty novice will find he has in his hand only a piece of dry cork-like rope.

It is practically impossible to judge of the age of the huge trees in these forests. Mighty with inherent strength, stayed to the ground and to their fellows by the numerous vines, sheltered and protected also by their fellows from the shock of storms, their huge trunks have little to do except support the direct weight of the tops, and they rarely fall until they have reached the last stages of decay. Then some day the sudden impact of a ton or two of water dropped from some furious tropical shower, or the vibrations from a hurrying troop of monkeys, or the spring of a tiger, is too much for one of the giant branches heavy with its load of vines and parasites, and it gives way, breaking the vines in every direction and splitting a huge strip from the main trunk. With its supports thus broken and the whole weight of the remaining branches on one side, the weakened trunk sways for a moment then bows to its fate. The remaining vines break with the resistless strain, and the old giant gathering velocity as he falls and dragging with him everything in his reach, crashes to the earth with a roar which elicits cries of terror from bird and beast, and goes booming through the quivering forest like the report of a heavy cannon. A patch of blue sky overhead and a pile of impenetrable debris below, mark for years the grave of the old hero.

As regards the insect and reptile pests of the country it has been my experience that both their numbers and capacity for torment have been greatly exaggerated. Mosquitoes, flies of various sizes, wasps and stinging ants exist, and the first in some places in large numbers; yet to a person who has any of the woodsman's craft of taking care of himself, and whose blood is not abnormally sensitive to insect poisons, they present no terrors and but slight annoyances. At our headquarters camp on San Francisco island, we had no mosquitoes from sunrise to sunset, and even after sunset they were not especially numerous. At another camp only a few miles away there were black flies only and no mosquitoes, at another both, while at the camps up in the hills there were neither. It was only at camps in the wet lowlands and near swamps, that they became an almost unendurable annoyance. Even here it was those who remained in camp that suffered most. Men out in the thick brush were but little annoyed by them, and when on their return to camp they had finished their dinner and gotten into their mosquito bars they were out of their reach. As to snakes, the danger from them even to a European, is practically nothing. Not a man of the several hundred that have been engaged in the various expeditions in that country has ever been bitten, and in hundreds of miles of tramping through the worst forests of the country, either entirely alone or if accompanied by natives, with them some distance in the rear, I have never fancied myself in danger. The poisonous snakes are invariably sluggish, and unless actually struck or stepped upon are apt to try to get out of the way, if they make any move. The only snake that is at all aggressive, as far as my observations go, is a long, black, non-poisonous snake. This will sometimes advance upon the intruder with head raised a couple of feet from the ground, or if coiled about a tree will lash at him with its tail.

The floral exhibit of these forests is apt to be disappointing to one whose ideas have been formed by a perusal of books. An occasional scarlet passion flower; now and then the fragrant cluster of the *flor del toro;* a few insignificant though fragrant flowering shrubs; and in muddy sloughs near the streams, patches of wild callas; are about all that meet the eye of the non-botanical wanderer in the deep forest.

There is not light enough for flowers beneath the dense canopy of trees, and they, like the smaller birds, seek the tree tops and the banks of the river where sunlight and air are abundant. In the tree tops the orchids and other flowering parasites run riot. Many of the trees are themselves flowering, and if one can look down upon the tree tops of a valley in March or April, he sees the green expanse enlivened by blazing patches of crimson, yellow, purple, pink, and white.

The river banks are the favorite home of the flowering vines, and there they form great curtains swaying from the trees in bright patterns of yellow, pink, red and white. The grassy banks and islands, and the shallow sand spits also bring forth innumerable varieties of aquatic plants.

So much for the Atlantic slope of the country.

On the west side between the Lake and the Pacific the work is very different. There it is possible to ride mule-back to the top of a commanding hill, sit down and make the reconnaissance sketch at leisure. The secondary reconnaissances may also be made mule-back, and everywhere the rolling country and the cleared and cultivated fields, permit the engineer to see where he is going and how he is going.

His surroundings are also different. He moves camp in an ox-cart instead of a canoe. His eyes instead of being confined by the impenetrable veil of the tropical thicket, feast upon views of the distant mountains, the crisp waves of the Lake, and the blue expanse of the Pacific. During the day he meets black-eyed and brown-limbed señoritas, instead of wild hogs and turkeys, and at night as he turns in, he hears, not the scream of tigers, but the songs of the *lavandera's* ecru daughters floating across the stream which supplies their wash-tubs and his camp.

The first grand natural feature which arrests attention in the most cursory examination of the map of Nicaragua is the Great Lake. This lake with an area of some three thousand square miles and a water-shed of about eight thousand square miles, is unique in the large proportion of its own area to that of its water-shed. A result of this large proportion of water surface to drainage area, at once evident, is the very gradual changes of level of the lake and their confinement within very narrow limits. The difference between the level of the lake at the close of an abnormally dry season and its level at the close of an abnormally wet season is not more than ten feet, and the usual annual fluctuation is about five feet.

The next features that arrest attention are, first, the very narrow ribbon of land intervening between the western shore of the Lake and the Pacific, and second, the entire absence of lateral tributaries of any size to the upper half of the San Juan River. The river is in fact, as it was originally most aptly named, simply the "Desaguadero" or drain of the Lake.

The length of this river is one hundred and twenty miles, from the Lake to the Caribbean Sea, and its total fall from one hundred to one hundred and ten feet. Nature has separated the river into two nearly equal divisions, presenting distinct and opposite characteristics.

From Lake Nicaragua to the mouth of the Rio San Carlos, a distance of sixty-one miles, in which occur several rapids, the total descent is fifty feet, quite irregularly distributed however. The surface slopes of the river vary from as much as 83.38 inches per mile for a short distance at Castillo rapids, to only .90 inch per mile through the Agua Muerte, the dead water below the Machuca rapids.

The average width of the river through this upper section is seven hundred feet, the minimum four hundred and twenty. In some parts of the Agua Muerte the depth varies from fifty to seventy-five feet.

There are very few islands in this section of the river, the banks are covered with huge trees matted with vines, and throughout the lower half of the division, from Toro rapids to the mouth of the San Carlos, the river is confined between steep hills and mountains.

As a result of the absence of considerable tributaries already noted, the fluctuations of this portion of the river conform closely to those of the Lake, and consequently take place gradually and are limited in range.

Below the Rio San Carlos the San Juan changes its character entirely. Its average width is twelve hundred and fifty feet, its bottom is sandy, there are numerous islands, and the slope of the river is almost uniformly one foot per mile.

The discharge into this section of two large tributaries, the San Carlos and the Sarapiqui, descending from the steep slopes of the Costa Rican volcanoes, causes much more sudden and considerable fluctuations of level than in the upper river.

While the lower portion of the river and especially the delta section presents very interesting features, yet the peculiar charm of the river is in the upper section, and the exceptional advantages it offers for obtaining miles of slack water navigation. This portion of the river with the lake and the narrow isthmus between it and the Pacific forms a trio of natural advantages for the construction of a canal, the importance of which it would be difficult to over estimate.

About three miles below the mouth of the San Carlos, the Caño Machado enters the San Juan on the north bank. This stream, about one hundred feet wide and from eight to ten feet deep, is the last of the mountain or torrential tributaries of the San Juan. It can scarcely be said to have a valley, but occupies the bed of a rugged ravine extending for several miles northerly and northwesterly up into the easterly flank of the cordillera. Every variety of igneous rock, from light porous pumice to dense metallic green-black hypersthene andesite, may be picked up in the bed of this stream. Agates also are common and there are occasional masses of jasper. Farther up, frequent outcrops of trap in situ occur, interspersed in some localities with numerous veins of agate.

Twelve miles below the Machado the San Francisco enters the San Juan. This stream, with its several tributaries, drains a large swampy valley sprinkled with irregular hummocks and hills. For several miles from the San Juan it is a sluggish, muddy stream between steep slippery banks ; higher up, flowing over a gravelly and then a rocky bed, it finally disappears in steep ravines filled with huge bowlders. The main San Francisco comes from the northwest, but a large tributary has its source to the eastward in a range of hills which separates the San Francisco basin from the immediate Caribbean water-shed. This range, unlike the ones already noted, is at heart an uninterrupted mass of homogeneous hypersthene andesite, and with one exception nothing but fragments of trap or trap *in situ*, is to be found in any of the streams descending from either its western or eastern slopes. The one exception is the Cañito Maria, a tributary of the San Francisco, entering it but little more than a mile from the San Juan. In the bed of this stream were abundant specimens of agates, jasper, and petrified woods of several varieties in a wonderfully good state of preservation.

This range of hills ends at the Tamborcito bend of the San Juan, four miles below the mouth of the San Francisco, and is the last easterly projecting spur from the mountain backbone of the interior. Between it and the coast there are, however, mountain masses of equal or greater elevation, notably "El Gigante" and the Silico hills, the former some fifteen hundred feet high, but these are simply isolated mountain ganglia, their innumerable radiating spurs speedily giving way to swamps or river valleys.

The streams that flow down the eastern slope of the Silico hills are, from their sources to the lowlands, of almost idyllic beauty. Beginning as noisy little brooks tumbling over black rocks in a V-shaped ravine near the summit of the hills, they rapidly gather volume and slide along in a polished channel of trap, tumbling every now and then as sheets of white spray over vertical ledges forming here and there deep green pools, and then after they have passed down among the foot-hills, rippling in broad shallow reaches over sunlit beds of bright yellow gravel. The water of these streams is clear and sparkling as that of an Alpine stream and apparently almost as cool. The insect pests of the tropics are unknown in the elevated portions of their valleys, and I have slept more than once beside one of these streams, several hundred feet above sea level, without a mosquito bar, while the delightful "trades," rustling through the trees above me, brought the murmur of the Caribbean surf miles away, to mingle with that of the stream.

The soil of this range consists, to a depth of ten to forty feet, of clay of various grades and colors, red prevailing. In the valleys this clay is almost invariably of a very dense consistency, and deep, dark red in color.

From the foot-hills of the range to the coast, is a low level stretch of country, a dozen miles wide, interspersed with lagoons and swamps. Near the hills, where the elevation of the ground will average about fifteen feet above sea level, the soil is composed almost entirely of the before mentioned red clay, which occasionally assumes the form of hummocks. Within about six miles of the coast this stratum of clay gradually disappears under a layer of sand, which is in turn covered, by a vegetable mould, to a depth of a few feet. From this point to the sea the average elevation is barely five feet above the sea level, and the sand and mould above mentioned are the only materials met. A short distance from the ocean the vegetable earth-covering disappears and only the sand is left, extending to an unknown depth and reaching out into the sea.

West of Lake Nicaragua, from the Rio Lajas to Brito, as we leave the lake shore, the ground rises almost imperceptibly to the "Divide" among cleared and gently undulating fields. Then we drop into the sinuous gorge of the Rio Grande only to emerge, a few miles farther on, into the upper end of the Rio Grande and Tola basin.

To the right the Tola valley stretches to the northward, and all around high and wooded hills encircle the valleys except directly in front where a narrow gateway in the coast hills opens to the Pacific. In the bottom of this valley are a few farms and through it wander devious roads. Beyond the narrow gateway in the hills, less than three miles of level swampy *salinas* reach to the surf of the Pacific.

The views from the hills which flank the gateway of the Rio Grande, at La Flor, are wonderfully attractive. I well remember one camp on the hillside, from which in one direction the eye takes in the fertile valley of the Tola and Rio Grande, backed by the rolling hills of the "Divide" and over them the symmetrical peak of Ometepe, its base washed by the waves of the great lake. In the other direction the Pacific lies apparently but a stone's throw below, the little port of Brito at one's very feet.

This same camp inspired one young engineer and enthusiast to express himself something as follows :

"What if, in this camp, we should, like Rip Van Winkle, sleep for ten years, and then awakening look about us? We are still at Brito, but instead of being in the wilderness, we look down upon a thriving city. In the harbor are ships from all ports of the world. Ships from San Francisco, bound for New York, about to pass through the canal and shorten their journey by 10,000 miles. Ships from Valparaiso, headed for New York, which will take the short cut and save 5000 miles and the dread storms of Cape Horn. At many a masthead floats the British flag, and vessels from Liverpool, with their bows turned towards San Francisco, have shortened their journey by 7000 miles."

"We go aboard one of the many steamers flying the "stars and stripes" and start eastward. All along the line the face of the country has changed; the fertile shores of the Tola basin are occupied by cacao plantations, fields have replaced forests, villages have grown to towns, and factories driven by the exhaustless water power furnished by the canal have sprung up on every available site."

"Along the shore of the lake are immense dry docks, and vessels are resting in this huge fresh water harbor before setting out again on their long voyages. The broad bosom of the noble San Juan is quivering with the strokes of tireless propellors. The roar of the great dam at Ochoa is heard for a moment and then the eastern section of the canal is entered. Here the country is scarcely recognizable so greatly has it changed. Wilderness and marsh have disappeared, and only great fields of plantains and bananas and dark green orange groves are to be seen. A day from Brito and the steamer's bow is rising to the long blue swell of the Caribbean at Greytown."

Well is this picture calculated to excite enthusiam, for it means the dream of centuries realized, the cry of commerce answered, and our imperial Orient and Occident-facing Republic resting content with coasts united from Eastport to the Strait of Fuca.