Ky. Geological survey, 1873-1891.

GEOLOGICAL SURVEY OF KENTUCKY.

N. S. SHALER, DIRECTOR.

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INTRODUCTION TO THE THIRD VOLUME.

As will be seen from the table of contents, this volume is an assemblage of the various Annual Reports of the Director of the Kentucky Surveys made during the years from 1873 to 1877, inclusive. The law requires these Reports to be made from time to time, and, prescriptively or by implication, demands that they each shall give a summary of the operations of the Survey, in a condensed form, for the information of the Legislature. It will therefore be seen that this volume must contain matters which have generally been more fully treated elsewhere. The text itself makes frequent references to the source of fuller information on these various subjects. The reader is, however, referred to the general index of the Survey publications, which will constitute the seventh volume of this series of Reports. It is now in preparation, and will be ready for publication within the coming year. Its appearance, however, will necessarily depend upon the continuance of the appropriations of the Survey.

The reader's attention is called to the fact that the work of the Surveys set forth in this volume has been hampered in many ways. In the first place, the appropriations at the service of the present Survey have averaged only seventeen thousand dollars per annum for all expenses, including printing. In the next place, the Survey has been required to concern itself with nearly all the material interests, and with all the scientific problems that are apparent in the State. Less money has been expended on the whole Survey than has been given to the printing of any one of several volumes of Government Surveys. The annual grant for all the purposes of the Survey, including geology, zoölogy, botany, archæology, the topography, the cabinet, and all the expenses of publication,

have been but about twice the sum paid by one State as salary to the Director of its Survey. It should be said, also, that the law provides for the employment of the Director for but a part of each year. The larger part of the Director's time, while engaged in the service of the Survey, has been given to the routine work of administration, so that his total field work has not exceeded about three months in each of the years of his service. The great size of the field of operations has made it necessary to have the work of the several assistants localized in various subdivisions of the area, so that the Director has necessarily been employed in keeping the various works in correllation the one with the other. While each Assistant is to be held responsible for his own opinions, and while their individuality has been considered to the utmost point, there are none of the various Reports of the several volumes which have not been carefuliy examined by the Director, who has, in all cases, read the manuscript and the final proof, and in many cases has repeatedly reviewed the matter. As the Survey has, at the present time, about four thousand 8vo and 4vo pages completed, or in advance preparation, this work of continual review has been equivalent to critically reading not less than twelve thousand pages of ordinary matter. To this labor must be added the task of writing an average of two thousand letters per annum concerning the work of the Survey, and making journeys that have demanded not less than thirty days per annum, in railway and steamboat transportation. Thus it will be seen that the Director of such a Survey has little time for special work in the field. The best that he can do is to secure unity and completeness in the work, occasionally putting his shoulder to the wheel to lift over some obstacle.

I cannot command words to express the lively sense of gratitude I feel to my fellow-workers of the Survey. Whatever shortcomings may be found in the work of the Survey, are not to be attributed to a want of zeal and fidelity among my Assistants.

I should gladly take this occasion to return thanks to the very many friends who have generously aided the Survey in a thousand ways; but as this list would include about all the citizens of the State with whom the Survey has come in contact, it will be impossible to undertake it. Space will only allow me to refer to the debt we owe to several of the railways of the State. To the Eastern Railway, the Louisville, Cincinnati and Lexington Railway, and to the Elizabethtown and Paducah road, the Survey is indebted for the frequent transportation of its officers, free of charge, to and fro from their field of work, as also the Louisville and Nashville road, for the privilege of half fare over their main line.

The very limited means at the disposal of the Director of the Survey has made these and other aids in its operations of the greatest value in furthering its work.

It is expected that the subsequent Reports, similar in nature to those in this volume, will find their place in the eighth volume of this series. A brief history of the Survey, from its inception to the time of publication of the seventh volume, will be found in the preface thereto.

N. S. SHALER.

DECEMBER, 1877.

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GEOLOGICAL SURVEY OF KENTUCKY.

N. S. SHALER, DIRECTOR.

GENERAL REPORT

OF THE

GEOLOGICAL SURVEY OF KENTUCKY.

BY N. S. SHALER.

PART I. VOL. III. SECOND SERIES.

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INTRODUCTORY LETTER.

To His Excellency, P. H. LESLIE, *Governor of Kentucky:*

SIR: When you did me the honor to appoint me Geologist of Kentucky, I was engaged in some work in England. A telegraphic announcement of the fact came to me on the 25th day of June, but matters which I had in hand delayed my return, so that it was not until the 22d day of August that I arrived in Frankfort and took the oath of office. Desiring to lose no time in getting to work, the same day I appointed, and you were pleased to confirm, Professor Robert Peter, M. D., of the Kentucky University, to be the chemical assistant, and Mr. A. R. Crandall to be the geological assistant in the Survey—thus completing the list of officers required by the law. The following day Dr. Peter began the organization of the laboratory at Lexington and I left for Greenup and Carter counties to begin, with Mr. Crandall, the work of completing the surveys of that district—it being provided in the bill for the reorganization of the Survey that the work should be a continuation of that done under Dr. Owen. As soon as this work was well under way, I returned to Frankfort and began a search for the records of the old Survey. To my great regret, I found that almost every thing had been destroyed by the burning of the offices of the State in 1869. The field notes, manuscript maps, &c., and all the valuable collections had been lost in this manner. After much search, I found, in Philadelphia, the copper-plate of the unfinished map of Greenup, Carter, Boyd, and Lawrence. This is worth several hundred dollars to the State. Dr. Peter had carefully preserved the materials in his hands at the time the Survey was suspended, so that something has been saved from the wreck.

The loss of the records of the Survey is the more to be regretted from the fact that the Legislature has ordered that

this Survey be a continuation of that made by Dr. Owen. As far as possible, I have complied with this order. Dr. Owen, however, left no distinct outline of his plan for the conduct of the Survey, and I have not been able to see clearly what his plan was from the most attentive study of his reports. I have, therefore, thought it best to sketch out a plan for the continuation of the Survey, with the intent of utilizing, as far as possible, the work that has been done, to the end that the Survey may be finished in the shortest possible time. This plan constitutes the first part of my annual report. My main object in bringing the questions involved therein before the honorable members of the Legislature is, that I might have their criticism and their warrant for the work I have undertaken, or may undertake. Any changes they may order will serve to limit and guide me in the work. You will see, by this plan, that I deem it for the best interests of the State to complete the work of the Survey step by step, making no report on any district until it is in itself final and complete. I therefore withhold the reports on the work we have in hand. I confidently expect, however, that the report on the counties of Greenup, Boyd, Carter, and Lawrence, will be finished and ready for publication during the month of February next. It will consist of about as much work as is embodied in one of the four published volumes of the Survey, with two maps and a number of important sections and diagrams. Work is now under way on the line of the Elizabethtown and Paducah Railroad, and owing to its more southern position, it will be possible to concentrate our energies upon this end of the State during the winter season. The work of mapping the line of the Lexington and Big Sandy, with a view to a report on the mineral and other resources along this line of road, has also been undertaken. Some progress has been made in the preparation of a report on the building materials of the State. I hope to have this completed within a year. With your advice and consent, I have communicated a number of letters to the journals of the State concerning its mineral and other resources. These informal reports will be contin-

ued from time to time. Large collections, illustrative of the mineral and soil wealth of the State, have been begun, with especial reference to the representation of the State in exhibitions to be held in the different American cities.

The following gentlemen are now employed in the work of the Survey: Dr. Robert Peter, assisted by Mr. John H. Talbutt, in the office of the chemical department, at Lexington; Mr. A. R. Crandall, Mr. Philip N. Moore, Mr. John A. Monroe, Mr. C. W. Beckham, and Mr. C. Schenk, in the field work. With myself, this makes eight persons employed, at an average cost of about twelve hundred dollars per month, including salaries, chemical supplies, subsistence, transportation, and repairs. No expense for rent or clerical labor has yet been incurred.

The following gentlemen have already engaged to act as local assistants, in accordance with the system recommended in the plan for the conduct of the Survey. The list is in the order of their acceptance:

W. T. Knott, Esq., for Marion county; Rev. J. M. Letton, for Mason; Rev. Dr. Cosby, for Nelson; Professor Failes, for Boyle; Dr. W. O. Graves, for Fayette and Clark; Col. Rand, for Lewis; Thomas Turner, Esq., for Montgomery, Menifee, Powell, and Wolfe; Redd Twyman, Esq., for Woodford; Dr. A. B. Lyman, for Madison; J. R. Anderson, for Adair.

I must acknowledge my obligations to these gentlemen, who, without reward, have offered their valuable assistance to the State.

The thanks of the Survey are due to Mr. Joseph Lesley, of Philadelphia, at one time assistant in the Geological Survey under Dr. Owen, for permission to use the plate of a map of the coal-field of Eastern Kentucky, prepared by him since the suspension of the Survey. This map represents the results obtained by one of the parties of the Survey during the last year of the work. I have also to acknowledge the kind assistance of the Eastern Kentucky Railroad, and also the many favors of its Vice President, Mr. Bates, and its Chief Engineer, Mr. Stoughton. We are also indebted to Mr. Kuper

and his assistants of the Lexington and Big Sandy Railroad, and to Mr. McLeod, the Chief Engineer, and Mr. Brock, Superintendent of the Elizabethtown and Paducah Railroad.

Despite the difficulties which always surround the beginning of any such undertaking, we have managed to accomplish a large amount of important work during the first three months of the operations of the Survey. The expenses which were incurred for outfit, though kept within the narrowest limits, exceeded one thousand dollars, two thirds of which was for chemical apparatus and supplies. By the first of January about one half of the appropriation of ten thousand dollars will have been expended, and the whole of the sum will be used by the first of next June. It is of the utmost importance that we should know, at the earliest possible date, what the future of the Survey is to be; for, under any circumstances, I desire to complete the work now in hand.

Let me say, in closing, that I have already seen enough of our resources to feel convinced that they need but to be properly set forth to the world to command wealth and prosperity for the State.

With great respect,

Your obedient servant,

N. S. SHALER,

State Geologist of Kentucky.

NEWPORT, KY., December 1st, 1873.

PLAN FOR THE CONDUCT OF THE KENTUCKY GEOLOGICAL SURVEY.

No such considerable work as the careful survey of an extensive and varied region, like the State of Kentucky, should be undertaken without a well-considered plan. I, therefore, propose, at the outset, to take up the questions involved in the work, to show the objects of the Survey and the means of accomplishing them.

The accepted object of a scientific survey of any region is to determine, with the aid of exact science, its relations to other parts of the earth, and the means whereby it may be made to contribute to the welfare of its inhabitants. Taking the successful and profitable surveys in this and other countries, we find the following means of gaining the ends in view:

1st. A general reconnoissance of the ground in order to secure the outlines of the problems which have to be met.

2d. The formation of an accurate topographical map, which shall give, on the scale of at least one inch of map distance for every mile of country, the exact relations of every stream, hill, and valley throughout the State.

3d. A Geological Survey which shall be so exact as to indicate, on colored sheets of this map, the precise limits of each formation; so that the owner of any land, by the use of this map, and the accompanying diagrams and reports, may be able to determine, as nearly as possible, what lies beneath it.

4th. A careful study of living animals and plants within the State, in order that their usefulness to man, the means of their nurture, or destruction and their relation to the fossil life, shown by the Geological Survey, may adequately be determined.

5th. The study of the physical conditions existing in the State—climate, magnetic variations, &c.

6th. The presentation of this knowledge in such fashion that may be best suited to secure its preservation and ready use within the State, and its dissemination abroad.

7th. The extension of the study of science within the State.

I propose to trace, in detail, the steps which should be taken to effect these desired results.

Fortunately for us, the preliminary reconnoissance of the State has been substantially completed. Nearly all the published results of the Survey of Dr. Owen were of this character. When he began his Survey the general outline of the geological formation of the State was unknown; the area of its coal-fields was a matter of conjecture. The utter want of knowledge of the State was a difficulty which could but be met by the cursory explorations which are recorded in the four published volumes of the Survey. During his years of service, Dr. Owen visited nearly every county in the State, and has recorded, in his successive reports, the important results of his quick and vigorous research. It is difficult to appreciate the value of this preliminary work. Unhappily, it was followed by five years of civil war, which not only broke up the Survey, but kept capitalists from the investments which they would have been disposed to make. Its desultory and fragmentary shape, evils, in good part, the result of the very ignorance of the work to be done, which it was its object to remedy, have made it difficult of access, to any one not a special student of geology. I am forced to confess that, after months of assiduous study, I am not yet complete master of its undigested mass of facts. After much consideration, and with the advice of my fellow-workers, I have resolved to do but little more of this preliminary work, which is costly to the State and wanting in the precision and completeness demanded in every geological report meant to be the base of economic work. I am now endeavoring to procure the required preliminary information in the following fashion: To many of the Senators and members of the Lower House in the State I have addressed a letter, asking of them assistance—each for his own county—in procuring information concerning the geological

phenomena found within its limits. Gentlemen of intelligence and some leisure, the clerks of the courts, sheriffs, physicians, and others, however ignorant of geology, can give me great aid. I have asked the honorable gentlemen of our legislative body to name to me some such gentleman in each county, who is willing to make himself the agent of the Geological Survey in procuring information. I have sought of them the following classes of information:

1st. What are the defects in the representation of your county on the maps you may have in hand? County lines, streams, and roads, how far are they in error?

2d. What are the mineral springs, or springs remarkable on account of their temperature, volume, variability, &c.?

3d. What are the minerals, coals, and building stones, as far as known? What mines, salt wells, and quarries have been opened? And what was the yield of these materials last year?

4th. What caverns exist in your county?

5th. What are the principal points where good sections through the rocks can be seen?

6th. What are the principal varieties of soils in your county, their natural timbering, crops, and the regions occupied by them?

7th. What are the timber trees, and how are they distributed in the county?

8th. What are the water-powers of your county, size of streams, character of shore, &c.?

9th. What is the price of land according to the character of soil, productiveness, and availability for immigration purposes?

10th. What remains of ancient races exist in your county?

This last item will lay the foundation for an inquiry into the history of our predecessors in the enjoyment of this land. This study must be made now, before the evidences are quite swept away by culture. I hope to gather by these inquiries the popular information concerning each county, which is pretty generally rich in well-observed facts. When these are collated with the observations made by the Geological Survey

of Dr. Owen, we shall, I trust, have for each county a basis for detailed work, which will enable me to begin final work therein with very great advantage. I am inclined to think that at least one third of the expense of the geological work can be saved in this way.

Whenever possible, I have aided these gentlemen, by advice and assistance, in making up local cabinets, which serve to illustrate the geology of their own particular region. The advantages of these local cabinets are very great; they serve to give people an interest in their own country, and will be an immense aid to the Survey when it comes to work in the regions where they are accumulated. But the most important result is to educate, in each district, some one person, who may become of inestimable advantage to his fellow-citizens by being constantly on the alert for indications which may be of importance, to which he will, if need be, call the attention of the officers of the Survey. A list of the gentlemen who have made arrangements to give this form of assistance to the Survey is given in the letter which precedes this report.

The gentlemen who have, without recompense, taken this work upon their shoulders, are entitled to the warmest thanks of their fellow-citizens.

The second division of the work of the Survey presents far graver difficulties than the preliminary reconnoissance. To make an accurate map of any country, on such a scale as that each land-owner may find a tract of a hundred acres or more fairly indicated thereon, is one of the first and most important works of any survey. Every State in Europe, and many States in this confederation, have incurred large expenditures in order to obtain this necessary basis for all important works. To the geologist, a map of this degree of accuracy is imperatively necessary if he would give his best work with the degree of accuracy necessary for economic results. His main end is to indicate, on a map, the precise outline of each geological formation, accompanying the same by diagrams, showing the succession of rocks beneath each district, and a detailed report on its geology, in such fashion that the resources at the

command of any land-owner may be accurately determined. It must not be supposed that it is to the geologist alone that such maps are necessary. As a basis for land surveys, in the construction of roads, railways, canals, and other improvements, such maps spare a large part of the expense which is now incurred in preliminary explorations, so that this map-making work may be regarded as a basis for the whole industry of the State. Most of the States in this Union were surveyed by the General Government. Ohio, Illinois, and Indiana, and the other States west to the Pacific, have had this work done in order to afford a basis for the division of the public lands. The State of Kentucky having been organized before the adoption of this system, never having been, indeed, a part of the Federal territorial domain, came into the Union without any survey whatever, and has to this day remained without any other delineation of its surface than has been given it by the chance work of several publishers. Taking the best existing maps of the State, we find they use a scale of four or five miles to the inch. Even with perfect accuracy and microscopic minuteness, it is not possible to give the necessary geological details. But a little study will show any one that these maps are mere bundles of errors. Streams are often ten or twelve miles out of place. Every railway survey shows many towns a mile or more from their true position. Indeed, it is not too much to say that the average error in the assigned position of the geographical features of Kentucky is several miles. Any geological mapping done on such an imperfect basis necessarily leads to an entire revision of the work in a few years, at a cost almost equal to the first expenditure. This shall not be, for I have fully determined that all the work done under my charge for this Survey shall be done with a definite plan, and to the final end of leaving the matter as far advanced as our sciences can take it. The revision that becomes in time necessary must be the revision coming from the constant increase of discovery, not from the original incompleteness of the work. A map, and that as good as modern science can produce, must be the very first object of the Sur-

vey. Five years ago I should have had grave fears as to the possibility of doing this work in a sufficiently accurate manner. In its nature extremely difficult, demanding the skill which is only found in a few large and long-trained governmental corps, the first steps of mapping an area, such as the State of Kentucky, are far beyond the resources of a survey such as the State can readily organize.

The former Geologist of the State, Dr. Owen, sought to escape from the difficulty by doing this work as part of the task of the Survey. In the six years during which the Survey was prosecuted, the greater part of its funds were spent on the topographical work. A base line was rudely measured across the State, and some maps begun; war, time, and fire have done much to obliterate the record of this work. On careful consideration, and by the advice of able counselors, I have determined that it would be imprudent to undertake to complete this map of the State. It can scarcely be said to have been begun, notwithstanding the large sums spent upon it; to carry it out on the scale proposed, would cost the State several hundred thousand dollars, and the result would be, after all, unsatisfactory, on account of the uncertainty of the basis of the work. In place of this work, it will be far better to avail ourselves of the aid of the United States Coast Survey, which is now offered to us, for the purpose of getting the triangulation of the State executed in a proper manner. The State of Kentucky can fairly claim the credit of having done much to bring about the extension of this good work in the interior States.

In 1868, Governor Stevenson recommended in his annual message the revival of the Geological Survey, and the passage of a resolution, by the Kentucky Legislature, asking the Federal Congress to allow the Coast Survey to give its aid to such Survey. In pursuance of this recommendation an item of sixty-five thousand dollars was entered in the appropriation bill, to be used by the Survey for such purposes. Unfortunately the State failed to pass the bill reviving the Geological Survey, and this money has been spent in work done in other

States; but I am promised by the Superintendent of the Coast Survey that the State shall have her share of the appropriation which may be made by the next Congress. This will secure to the State an amount of money probably much exceeding the sum appropriated for the use of the Geological Survey. As the triangulation is completed, we shall obtain a number of determined points, so great that it will be possible to construct, at small expense and with great accuracy, maps on which the geology of the country can be satisfactorily represented. I therefore venture to recommend that the Legislature be requested to memorialize the Federal Government to increase the Coast Survey appropriation, so that the work may be energetically prosecuted in this State. As at least a year must elapse before the work done by the Coast Survey will begin to serve as a basis for final maps of the State, I propose the following plan for the work to be done in the interior, until the maps can be made. Most of the railway surveys of the State have been made with sufficient care to give us, with an approximation to accuracy, the surface of the country for some distance on each side of their lines. With reductions of these maps in hand, it will be a comparatively easy matter to color them geologically, and to prepare detailed reports of the soils and minerals to be found along their lines. The aggregate length of the several lines of railway already built, or about to be built, is about one thousand five hundred miles. If the surveys will give a basis for mapping, for the distance of five miles on either side of the lines, then the work will include about the third part of the surface of the State. This will afford data on which to solicit immigration, and the investment of capital in those regions which have been made readily accessible by these roads. Printed in a simple way, and distributed broadly, these reports will make the most effective possible basis for the development of the State. With proper care, this work can be done in a fashion which will not make it necessary to have it revised in order to bring it on to the final map of the State. It may, therefore, be regarded as no temporary expedient.

Although I am compelled to limit the work which has a final character to the region where railroad, river, and other surveys supply the basis for maps, I shall not hesitate to extend my researches to regions remote from transportation, and to make such reports thereon as may be necessary to inform capitalists who propose to invest money in mines, &c., or to encourage citizens to take the steps necessary to provide adequate conveyance for their mineral wealth. Should the demand make it necessary, I will, besides the time I may be able to give to it myself, appropriate to this purpose the services of a competent assistant, whose whole time shall be given to making special surveys in aid of the development of various projects which are likely to prove successful.

The development of the coal and iron of the State will necessarily be the first object of the Survey. Though other States may have a larger area of these materials, a careful comparison of our own stores with those of other countries has satisfied me that when we consider the extent of our coal and iron fields, their relation to the most extensive system of fresh water transportation in the world, their neighborhood to the fertile lands of the central region of the State, and the vast markets of the West and South, the admirable system of rivers which penetrate them, and only require small lockage to make natural canals for the discharge of the products of quarry and mine, and finally the admirable position for working in which the beds lie, we are justified in placing Kentucky the very first in natural wealth of all the States in the Mississippi Valley. But our first object should not be to arouse the export of these products alone, but rather to show the way in which the future of our industries can be so managed as to induce capital to seek to combine our products within our borders, to convert the coal and ore into iron, and this iron into its products, rather than to ship them abroad for other hands to work. The richest States are not always those which produce the most of the raw materials of industry, but rather those which utilize these materials most effectively within their borders. I shall, therefore, not hesitate to make the work of

the Survey do all it can to throw light on the questions of industrial improvement, by giving the statistics of mines, furnaces, &c., by showing the natural routes of transportation as dependent on the structure of the State, and all other similar matters.

In doing the geological work along these railways, the utmost care must be taken to record the whole of the observed facts in such fashion that this record may remain a permanent evidence of the Survey,apart from any theory or opinion which may be based upon it. Let it not be supposed that I would condemn the explanation of observed facts, which constitutes theoretical geology. I only wish to enforce the importance of keeping the evidence of the facts in a way which will, at any time, allow the conclusions to be revised without the expense of collecting the evidence again. The following plan for the collection of materials has been adopted, and the work is being done in pursuance therewith. The note-books of each assistant working in the field are to be kept with all possible detail, and made a part of the records of the Survey. As these books will represent the fact of each observation, with proper drawings for illustration, their testimony will always be useful. But the most effective way of recording the observations made, is by carefully collecting specimens illustrative of each formation and preserving them, with such descriptive labels as are necessary to show their position and relation. These specimens should be made to illustrate the resources of the State in the most ample manner. Enough should be gathered to enable us to make several collections; the first and most important to be deposited in the State University at Lexington, where the students of our principal school may gain an adequate idea of the resources of their native Commonwealth, while they are studying the means to be used in its development; another collection should be deposited at the Capital; and yet another, or possibly two, be used as a means of representing the State in the exhibitions which now play so prominent a part in the industrial life of this and other countries. These collections

should be made to represent, in an ample fashion, the following features:

1st. The geological and mineralogical features of the country.

2d. Its soils and their cultivated productions.

3d. Its native animals and plants.

4th. Its ancient life, both of animals and man.

So close is the dependence of all the forms of life upon the geological conditions of its surface that all the matters above specified properly fall under the attention of the geologist. Moreover, it will be desirable to give, along with these collections, maps showing what is known of our climate, water-powers, and other features bearing upon the condition of the State.

One of the advantages to be derived from making our first studies along the railroad lines is the ample facilities afforded for transportation of such collections, as well as the good views of the rocks, soils, &c., given by the cuts of the roads.

Considerable collections have already been made with a view to the exhibition above referred to; experiments have been made as to the methods of display; and the details of the plan are set forth in Appendix A.

Some work is also doing toward the representation of the fossil contents of our rocks. It is not alone for their great scientific interest that these objects demand our attention. They have the clearest and most immediate practical value. Many times the money required for the Geological Survey of the State has been expended in profitless searching for coal, oil, and other materials, in regions where they are known to be wanting by trained geologists. It is through the fossils, and in many cases through them alone, that we are able to identify any stratum and determine its position. Therefore it is imperatively necessary, in any geological report, to show the forms of animal life characteristic of each level. They are the inscriptions upon the rocks which tell their date and their history.

A special object of the Survey will be to examine the building materials of the State, at least those which are useful in masonry work. I am satisfied, from the work which has already been done, that the best building stone in the West, when we consider their quality and accessibility to water transportation, lie within our State; and yet, with all this store, the Federal Government has been compelled to pay half a million dollars for a less enduring stone, brought from the distant shores of Maine, over a thousand miles away. A plan for this collection is shown in Appendix B.

By far the most important means of studying the resources of the State, and contributing to their increase, is to be found in the chemical laboratory. In the present state of our science, no step forward can be taken without its aid. The maker of iron and all other metals, the cultivator of the soil, the builder, the domestic economist, must all ask this aid. The very first step taken in reorganizing the Survey was to reappoint the able chemist of the old Survey, and arrange for the starting of the laboratory. An arrangement was made with the Regent of the Kentucky University, at Lexington, by which rooms were secured, rent free, at that central point. As a good deal of apparatus had to be purchased, and many other arrangements made, this laboratory was not in order for work until the middle of September. The report of the chief chemist will show the condition of the work in that department. Besides the work directly connected with the Survey, this laboratory will give to all citizens of the State a chance of having analyses made at less than one fifth the usual rates. The chief chemist, or his assistant, will be glad at all times to give advice concerning the prosecution of any work which demands chemical knowledge, as far as may be consistent with their other duties. It is especially to be hoped that the farmers of the State may avail themselves of this admirable opportunity for improving the culture of their fields.

An important work of the laboratory will consist in the preparation of a report on the mineral springs of the State. Kentucky abounds in waters of this description. There can be

be easily effected in connection with the geological work and the study of our fishes. The expense will be little more than the cost of printing the report.

That assemblage of physical conditions we call the climate of the State should also be carefully studied. Depending, as it does directly, in a great measure, upon the geology of the region, it fairly comes within the limit of a geological survey. Furthermore, as the all-important questions of health, of products, of history, indeed, depend upon it, it must be regarded as the crowning work of any survey. I think it is quite possible to secure the aid of the United States Signal Service Corps, so that the State may be spared the cost while reaping the advantage of this work.

The method of publishing the results of the Survey demands the utmost attention. Nothing can be more impracticable than the means ordinarily adopted of bringing such information before the people. In the first place, the crowding together, in the shape of annual reports, of all the different materials, geological, chemical, zoölogical, not even so arranged that the facts concerning particular districts can be found together, is opposed to all purposes of utility. If we take the ordinary run of annual reports of geological surveys, we find that it is extremely difficult to get a clear idea of the geology of any particular district, so widely scattered is the information which bears thereon. The ordinary citizen, inexpert in such special work, finds it well nigh impossible to obtain definite information from this source. The defects in the methods of distributing the reports are almost as great as in their form. From five to twenty-five thousand copies are thrown suddenly upon the State; given away to every applicant. For a while they are as plentiful as patent-medicine almanacs, and about as little cared for; but the chances of the household soon waste them, until, in ten years, they become the most rare of books. I have been trying for two months to buy a few sets of the reports of Dr. Owen, and failed to get a single copy of the first volume. I am inclined to think that there are not two hundred copies extant at the present time (there were

five thousand printed), and these are mostly out of the State. Many counties could not furnish a single complete copy. I am constantly asked by scientific men, and by persons about to invest money in the State, where they can obtain these volumes, and am compelled to leave their demands unsatisfied. To avoid these difficulties, which come from want of order and from want of permanence in the reports, I venture to propose the following plan for the publication of the Geological Survey. Let me say, at the outset, that it is modeled on the system followed in the Geological Survey of Great Britain, the most economical, as well as the most successful, of surveys.

In addition to the general reports, which may include matter which applies to the whole State, let there be special reports on the geology of each district, limiting these to counties, or to small groups of counties, as the work may make desirable. Each of these reports, whether special or general, should represent work which is completed as far as the resources of the Survey will admit. For instance, the report which will be presented in a geological section, including Greenup and a part of Carter, of Boyd, and of Lawrence, will represent all the work done by the Survey in this region, and will be complete as far as it is in our power to make it. All that can be ascertained concerning the iron, coal, and other minerals, the building stones, timber, springs, soils, &c., &c., will be represented in the map and reports of this district. As soon as the Government Survey is far enough advanced to give us new maps, we shall proceed to complete counties and groups of counties on the same fashion. The general reports should include such matters as the general geology of the State, arranged in a way to be used as hand-books by immigrants and others, a report on the mineral waters of the State, one on the soils and natural manures, &c. By this arrangement, the use of the information gathered by the State Survey will be greatly facilitated.

I have already begun accounts of the mineral resources along the line of the Lexington and Big Sandy, the Eastern

Kentucky, and the Elizabethtown and Paducah Railways. With the aid of my able and zealous assistants, I hope to have these done by the middle of the coming summer, and to be able to take up the work along other lines of railway. Each of these reports may be expected to contain a map of the line, and as much territory on each side as can be profitably worked for its ores, timber, &c.; the necessary sectional views prepared with accuracy, yet in the simplest and least technical language, and a detailed report of the geological and agricultural resources of the line of country traversed. In a simple form, and with cheap printing, these reports need not cost over twenty to thirty cents a-piece, so that they can be distributed by our railways, at their own expense, with great advantage. In the publication of the economic results of the Survey, it must be kept steadily in mind that the immigration of capital and labor is wonderfully affected by advertisement. Other States, by making their small resources widely known throughout the world, are drawing to themselves the capital and energy which is always seeking new homes; we, with our noble resources, are making no headway.

With this method of publication we should have a method of distribution quite different from that usually adopted. The reports should be stereotyped, and not over a thousand copies printed at the outset. Of these, one copy should be given to each member of the Legislature; fifty copies given to public institutions; one copy of each general report filed in every county court; the special reports should be also supplied to each county interested therein. The remainder should be put on sale at the cost of production. The demand would probably require of each general report about an average of two hundred copies a year, and of the special reports about half this number; but every volume so distributed would be an immediate source of usefulness, and at the end of ten years, in place of one twentieth of the copies surviving, at least nine tenths would be in positions to advance the interests of the State. The cost of publication to the State would be not over one half what it would be under the old system, and the effect-

iveness would be beyond measure greater. As I said before, the British Survey, where the experience runs over fifty years, and a great variety of experiments have been had, is distinctly in favor of this method of publication and distribution. The State of California, where there is now in progress the most admirable Survey which has ever been undertaken on this continent, equaling, if not surpassing, the best European work, follows the same plan of distribution.

Besides the printed evidences of the work done by the State Survey, the collections it makes, and their proper display, merit a great deal of consideration. I have already referred to the most important matters in that connection; its importance justifies me, however, in calling special attention to the question of the display of the resources of the State at the Centennial Exposition at Philadelphia in 1876. By taking pains to prepare for the smaller exhibitions to be held in Louisville, Cincinnati, and Chicago, in the next three years, we shall, by 1876, have a better basis for the illustration of the State than any other Survey is likely to have. An annual expenditure of less than one thousand dollars, for five years, will enable us to do this, and will leave the collections in our hands for use at the Capital, and at the State University. It needs no argument to show the desirability of making a proper exhibition at Philadelphia. The estimate that the world at large will form of the several States of our confederation will largely depend on the show made by them at this, our first truly national exhibition.

I have already elsewhere incidentally indicated the principal means whereby the Geological Survey can be made to advance the general interests of science in this State. Some efforts towards this result are to be found in the connection which has been made between the laboratory of the Survey and the University at Lexington. This arrangement will extend still further. The senior geological assistant, Mr. Crandall, during the months when the weather is too bad to make his labor profitable in the field, will be employed by the University, as a teacher of geology, without expense to the Survey. This post

will enable him greatly to extend the knowledge of the State among its growing youth. The selection of local agents of the Survey in each county, gentlemen who are willing to become special students and fellow-workers of the Superintendent in the investigation of their districts, cannot fail to do something towards developing an interest in such matters. I am, moreover, satisfied that it is desirable to have in the employ of the Survey at least half a dozen young men, who have selected mining or civil engineering for their profession, who, having their expenses paid by the Survey, will receive their remuneration in the training the work gives them. Much of the mere mechanical work of the Survey can be done by young men with half a year's training. Even as a measure of economy, this system would commend itself for adoption; but the advantage of having in constant training a half dozen selected youths, who will keep their training at the service of the State, cannot readily be over-estimated. A grave disadvantage connected with the former Survey was, that, with a single exception, none of the half dozen persons employed were residents within the State, and not a young man was trained to its service during its five years of useful work. I am satisfied that, with care, each year of the work can be made to train several young men to the knowledge of the resources of the State, and this without much extra expense to the Survey.

While every effort should be made to bring the largest material return for the expenditure of the Survey, the questions of economy and practicality should not narrow its bounds or hamper its work. A great Commonwealth endeavoring to set before the world its wealth of resources, cannot measure every step by its immediate profit. The questions which seem to be purely scientific, demand the same attention as those which bring us at once to cash in hand. The time has passed away when an arbitrary division could be made between the knowledge that pays and that which does not. The abstract science of to-day is bread for millions in ten years of time. Twenty years ago, a speculative German spent his time in

studying the spectrum of the sun with a microscope, trying to find what gases were flaming in its atmosphere; to-day his work helps to make the Bessemer steel process a possibility, and is one of the keys to an annual product of one hundred millions of dollars, and an industry which is to revolutionize our arts.

This is but one of very many cases where science, the most impracticable in appearance, is the most practical in its results. The true economy is to believe that truth is wealth, and seek it wherever it can be found. A survey having this principle for its guidance, will do much to give our Commonwealth its true place among States.

APPENDIX A.

MUSEUMS OF THE STATE.

1st. The geological and mineralogical collections.

The object of these collections should be to exhibit the following features:

(A.) The succession of rocks and their contents, from the base of the section within the State to its uppermost member, with such illustration, drawn from other countries, as may be necessary for its explanation. This collection should include, besides the older rocks, fossils of post-tertiary times.

(B.) A mineralogical collection, including specimens illustrative of the metallurgy of the State, ores, coals, slags, and their products.

All these materials should be accumulated in such quantities that these collections may be triplicated, at least, in their most important features. Specimens of ores should include at least 200 cubic inches of each kind. All important specimens should be accompanied by a sketched section, showing the precise relation of the mass to its surroundings. Whenever possible, the specimens should be numbered corresponding to label and catalogue.

2d. Museum of soils and cultivated products.

The first object of this collection should be to show the full history of the soils of the State, their derivation, their original condition, the losses from cultivation, and the means of their restoration to original fertility, or of elevating them above their native state. The collection should consist of four samples of each important variety of soil, representing: 1st. The surface soil as worn by culture; 2d. The subsoil beneath the same; 3d. The rock whence derived; 4th. The virgin soil of the same quality, if it can be obtained. These should be exhibited in glass bottles, arranged one above the other on proper shelves; along with them there should be full descriptions of the soils, their products, proper culture, &c.; the chemical analysis, with a list of the deficient materials, with notes of the best means of restoring the lost elements by manuring, or by rotation of crops, fallowing, &c.

The collection of cultivated products should be arranged with special reference to the illustration of the soils and the action of manures. In the collection of this museum the aid of the agricultural societies should be sought.

In this museum should be shown the results of manuring, as shown by the change in the analysis of the soil and the product—this with special reference to the manures to be obtained from the marls and limestone beds of the neighboring country.

3d. Museum of woods and other native botanical products.

The special object of this collection should be the illustration of the valuable timbers of the State, as well as the other botanical products which may be of importance.

APPENDIX B.

BUILDING MATERIALS.

The building materials of this State should have an ample illustration. They at present represent industries requiring a capital of over a million of dollars, and will in ten years

probably quadruple this amount. The failures, due to the want of knowledge of the distribution of the building stones in the lower silurian rocks of Campbell county alone, would support the Geological Survey for at least two years.

The most important of these industries are in connection with the following materials:

1st. Building stones, sandstones, limestones, and flint stones.

2d. Brick clays.

3d. Fire-clays.

4th. Water cements and limes.

5th. Timber.

The museum of building stones should, among other specimens, include several blocks of each important variety, to be exposed in the open air. The most admirable feature connected with our Kentucky marbles and sandstones, is their effective resistance to the decay usually brought on by the action of the atmosphere.

The building stones accessible to water transportation in Kentucky are, on the whole, the best in the West. A careful series of experiments, serving to show in an accurate way their resistance to decay, will be calculated to aid their introduction into use. In the month of September the Federal Government awarded a contract for building stone, to be used in the new custom-house building in Cincinnati, to a firm of quarriers in Maine. A safer building stone, more enduring, and of a far better architectural effect, can be quarried on the banks of the Kentucky river at half the expense of the transportation of building materials from that distant point.

The woods of the State should also be shown, with special reference to the decorative timbers in which our State abounds. Care should be taken to point out the distribution and relative abundance of the several species of trees in different regions. With a view to this, and of showing the relative abundance of different species at different points, it will be necessary to select, in each region, several acres of virgin forest, and by counting the several species, determine the per cent. of each

kind in the given area. Then, by taking the size of the largest, it will be possible to describe the forest resources of the State in a way calculated to show clearly their surpassing wealth.

The brick clays of the State are numerous and more varied in character than is commonly believed. These should be represented along with the pottery clays, of which there are several good, though unused sources. It is especially desirable that this latter industry should be fostered, inasmuch as it can be introduced with little capital, and will fill a want which is now supplied from foreign sources.

The fire-clays of the State are of great value, and only require a small investment to give them a high place among the resources of the States. In England the mines of this material are among the most profitable in the kingdom. The demand is daily increasing; while the amount of material of good quality is so small that the supply is not likely to overtake it. I shall seek to have samples of the best forms made into the several articles for which it is fitted, and exhibited in our collections.

Along the banks of the Ohio, the Licking, and especially along the Kentucky, we have the combination of cheap coal, and accessible limestone and cement stone, which goes so far to make the production of lime and cement profitable industries. When the improved transportation on these rivers brings coal and carriage to the minimum, there can be no doubt that these articles will make an important source of commerce.

APPENDIX C.

ESTIMATE OF THE EXPENDITURE FOR THE SURVEY OF THE RESOURCES OF KENTUCKY, FOR THE YEAR FROM JANUARY 1ST, 1874, TO JANUARY 1ST, 1875.

For the pay of persons employed in the geological work—five in number, including the Superintendent	$6,500
For the transportation and subsistence of geological parties in the field, eight months in the year	2,000
For the work of an assistant employed as special student of the fisheries, including subsistence and transportation	500
For pay of persons employed in map-making	1,000
For the pay of chemist and assistant	2,500
For the purchase of chemical supplies	500
For the expenses of forming and exhibiting collections illustrative of the State's resources, including show-cases and transportation	1,500
For the support of two aids or apprentices of the Survey	500
For the expenses of printing the reports of the Survey	2,000
For the construction of two wagons, the purchase of horses, &c., for camp outfit	1,200
	$18,200

With expenditures on this scale, I shall be able to prosecute work at four points at the same time. The sum is much less than the annual appropriations of the States of Ohio, Missouri, and California.

As I hold it improper for a servant of the State to withhold the whole truth concerning the work put into his hands, I have, against the advice of some counselors, made a careful estimate of the time required to complete the work in the State.

The time required will be determined in a great measure upon the work the State concludes to have done, supposing that we keep the following points in view—

1st. The preparation of a succinct account of the geology, etc., of the State, treating it by counties, with a general geological map on a small scale. The whole meant to fill one volume of moderate size, of a nature calculated to attract immigration.

2d. The preparation of maps of each railway line, and a report giving the geology, soils, productions, timber, water-powers, etc., within ten miles or more on each side.

3d. A report on the mineral springs.

4th. A sufficient account of our fossils to make the determination of our rocks a possibility.

5th. A report on the fisheries of the State.

This would require, I estimate, three years from the 1st of January, 1874, with an average annual expenditure, including printing, of about fifteen thousand dollars per annum. I do not think it need run over seventeen thousand at the outside. When the work comes to this point, the United States Coast Survey will have given us a thorough triangulation of the State, at an expense much greater than the geological work. If the State then elects to complete its geological map on a large scale, so that each land-owner can see for himself just what he has below his soil, then it may be necessary to have some years more life given to the Survey. This reckoning need not be made now. I am, however, so sure that the Survey will prove the key to a new access of vigor and prosperity to the State, that I am confident that its authorities will seek to continue it until its fullest work is done.

It is important to note, however, that, to work economically, it will be necessary to enable the Director of the Survey to be able to forecast the work of the three years, by voting the appropriation for that time; men can be hired for much smaller recompense when its duration is to be reckoned upon. I must say also that the estimation of the cost of such work is quite difficult, and is liable to some errors.

N. S. SHALER,
State Geologist of Kentucky.

GEOLOGICAL SURVEY OF KENTUCKY.

N. S. SHALER, DIRECTOR.

HISTORY

OF THE

OPERATIONS OF THE SURVEY

IN 1874 AND 1875.

BY N. S. SHALER.

PART II. VOL. III. SECOND SERIES.

OPERATIONS OF THE SURVEY

FROM 1854 TO 1860.

The Geological Survey of Kentucky was authorized by an act of its Legislature in 1854; in the same year Dr. David Dale Owen was appointed State Geologist, and the work was begun by him in the summer of that year. This work was commenced at a time when the very outlines of the geology of the State were but imperfectly known; it was therefore at first necessarily directed towards the end of securing a general account of the geology of the State, such as may be obtained by a rapid reconnoissance. This preliminary study, which should precede all deliberate and organized geological work, was carefully and expeditiously carried on, and the four volumes forming the annual reports of Dr. Owen and his assistants, constitute a sufficient record of one of the most successful preliminary surveys ever undertaken in this country. Along with this general reconnoissance of the State, the record of which forms the larger part of these reports, we have a certain number of reports which have a more special value. The elaborate and valuable chemical reports of Dr. Robert Peter, the reports of Mr. Leo Lesquereux, and some other special reports, have a value as scientific contributions, independent of their worth as aids to the making of a final and detailed survey. But as a whole, the report of Dr. Owen may be regarded as furnishing only the basis on which a detailed study of the economic and scientific questions can be founded. In 1860 the death of Dr. Owen and the forebodings of the disastrous civil war, led to the discontinuance of the Survey; and it was not until thirteen years after, that the condition of the State, in the judgment of the Legislature, admitted a revival of the work. In the session of 1872–'3, an

act was passed giving the sum of $10,000 for the resumption of the work, it being expressly stipulated that it should be taken up just where it had been left off by the survey of Dr. Owen. In order to set clearly before the reader's mind the position in which the reorganized survey was placed by this obligation to continue the work of Dr. Owen, it will be necessary to give a brief sketch of the operations of the Survey during the time when it was under his direction. As before remarked, the work done by Dr. Owen and his assistants was essentially a reconnoissance, and was necessarily directed to the end of obtaining an outline of the general geological structure of the State. In the first of his annual reports, the general report of Dr. Owen, occupying 250 pages of the volume, is given to the description of his reconnoissance of the western coal field of Kentucky, and some notes on the observations made by himself and assistants in the eastern part of the State. The first part of this report is an able, and on the whole satisfactory, sketch of the general outlines of the geological structure of western Kentucky; the second part is more fragmentary, and is open to criticism on several important points. Following this general report of the principal geologist, we have the report of Dr. Robert Peter, the chemical assistant of the Survey, the first of the series of extensive and admirable reports on the analyses of coals, ores, soils, &c., which have already served to carry our knowledge of the chemistry of Kentucky beyond that of any other State in America. In the 180 pages of this report we have about two hundred analyses, with a somewhat extended discussion of the most important of them. The remainder of the letter-press of this volume is occupied by a report of Sidney S. Lyon, topographical assistant, which gives a combined geological and topographical report of the map-work done in western Kentucky, in a part of Union and Crittenden counties.

In twenty pages of letter-press we have a brief description of the topography of the region; some facts of only trivial importance concerning the geology, and a recommendation for

the survey of a base line from the mouth of Highland Creek, in Union county, to a point on the Virginia line, in Pike county, due east of the first named place. This line, it was proposed, should serve as a basis whereon to build the successive maps of the State, which were then in contemplation. The execution of this project was begun in the subsequent year. The most important matter in this volume, from an economic point of view, is the chemical work, and the various diagramatic sections placed at the end of the volume. The latter give the first general statement of the structure of the State in a shape to be generally understood.

The second volume of Dr. Owen's report contains his second annual report, and those of his chemical and topographical assistants. Dr. Owen's report begins with a discussion of the importance of the chemical study of the soils, and contains much practical advice, which has doubtless been of value to the State. This general discussion is followed by an extended consideration of the data given by the analyses already made by Dr. Peter. This chapter, occupying about fifty pages of the report, is followed by a dissertation on the coals, ores, &c., which had already been examined. In it attention is called to many important sources of wealth in the building stones, mineral waters, &c. A large number of the important waters of this class, occurring within the State, were submitted to a qualitative analysis by Dr. Owen, in a fashion suited for reconnoissance, but not valuable as final work. The general geology of the State was also materially advanced by many accurate sections made by him, and published in this report. His great industry may be seen in the number of counties over which the reconnoissance had been extended during the operations of this year.

The report of Dr. Robert Peter contains the analysis of two hundred and six different substances, including seventy ores and forty-three soils. Appended to the special reports is a general statement of the method pursued in collecting the soils, and something concerning the methods of analyses with the coals, &c. At the close of his report we have a set

of carefully arranged tables, wherein are grouped, under appropriate heads, all the analyses which had been made for the Survey up to that time. The last seventy pages of the volume are taken up with the report of the topographical assistant. This includes an account of the work done in reconnoitering or mapping, in part, of the counties of Hopkins, Crittenden, Livingston, Caldwell, Christian, and Henderson, in the western part of the State, and of the counties of Greenup and Carter, in the eastern part of the State. There are also some incidental notes on parts of Bourbon, Bath, Fleming, and Lewis counties. The report closes with a brief statement of the progress made in the survey of an east and west base line, which had been proposed in the preceding report. The report, which is very brief, and gives a most unsatisfactory account of the means taken to carry out this important work, closes when the line had been carried about sixty miles from the point of departure. There are no maps or sections appended to this volume.

The third volume begins with a chapter on the coal measures, giving a general account of their beds as far as they had been developed at that time. A good many of the conclusions given have been much limited by subsequent discoveries; but the rapid progress in the reconnoissance made by the Survey shows itself in the general clearness and accuracy of this sketch.

The second chapter discusses the operations of the Survey in the study of Kentucky soils—over two hundred had already been collected. This essay, together with the following report of Dr. Peter, forms an admirable general account of the soils of Kentucky. The third chapter gives the qualitative analysis of a number of mineral waters not before examined. All this work is strictly preliminary, and may be regarded as belonging to the reconnoissance of the State. Next we have the general report of the reconnoissance made by Dr. Owen, being simply the jottings of the things seen in a rapid survey of the counties through which the reconnoissance had been carried. Every county of the State had now been visited in

a preliminary way, and in a certain sense, the reconnoissance of the State had been finished.

Some part of this work, however, had been conducted with so much haste that it could not be regarded as sufficient for even the most general purposes. The chemical report in this volume includes analyses of two hundred and twenty substances, more than one half being soils and under-clays. The work is summed up in a series of tables at the close of the report, giving, in a compact form, a complete list of the chemical constituents of each soil or other substance analyzed during the year.

The last report of this volume is, in effect, a continuation of the report of the topographical assistant of the work done in Greenup, Lawrence, and Hancock counties. In it, as before, we have a combination of geological and topographical results of the surveys in these counties. It contains many well-made sections, illustrating the rocks of these districts. There are some general conclusions, hastily drawn, concerning the structure of the Greenup county district. This part of these reports has been discussed in the report on this district by Mr. A. R. Crandall, geological assistant of the present Survey.*

Immediately following this report we have another by the same author, on the paleontological results of the Survey. In it a number of species of crinoids, principally from the neighborhood of the Ohio falls and from Crittenden county, are described. This report was accompanied by five plates, illustrating, in a very satisfactory way, the fossils therein described. The progress in the study of the fossil contents of our rocks is marked by the addition of two other valuable paleontological memoirs to this volume; one of these, by Dr. Leo Lesquereux, concerns the flora of the coal measures of western Kentucky. It was substantially an attempt to identify the coal beds, and determine to which of them a particular bank might belong, by a study of the fossil coal plants found in the shales overlying the several beds of coal. There is also an excellent description of the process by which coal is

*See Reports first volume, new series, page 1 et seq.

formed, which has a peculiar value, coming from one of the most learned students of the phenomena of coal beds.

Following this is a detailed review of the coals of western Kentucky, based upon the fossil plants associated with each bed, but those formed especially in the shales above it. In this examination, the investigator has assumed that the successive beds will have different assemblages of plants fossilized in their substance and in the neighboring shales deposited at about the same time. Whatever may be the opinion concerning this method as a means of determining the identity of beds of coal, there can be no doubt that the investigations which are recorded in these pages of Mr. Lesquereux's report, are substantial contributions to the study of an extremely difficult and important problem, and that they constitute one of the most important parts of the work done by Dr. Owen's survey.

The experience of the officers of the present Survey in this field has been such as to diminish, in some degree, the confidence with which these determinations have been held; but there is no doubt that the final judgment will go far to support the claims of this method of fixing the identity of coal beds, though it may not give it the first place among the means of forming an opinion on this point.

This volume is closed by another paleontological report, by Mr. E. T. Cox, on the fossil mollusca of the western coal field. This was meant to be a companion report to that of Mr. Lesquereux, on the vegetable fossils of the same region. Twenty or more fossils, believed to be new to science, were characterized in brief description, and illustrated with good figures. Although quite insufficient, these descriptions served a good purpose in their day, in calling attention to an important series of marine, inter-carboniferous strata. There is an admirable field for the paleontologist in these extensive beds, which mark the successive, wide-spread invasions of the sea into the heart of the land of the coal time.

The fourth and last volume of the series of reports made under the superintendence of Dr. Owen, is in many regards

the best of the series. It is clearly seen, from an examination of this large volume, that the five years of work, which preceded its beginning, had led steadily towards a right understanding of the problems of our geology. At the same time, it records the unhappy events which interrupted the course of the Survey. Dr. Owen's own report is very brief, occupying only about forty pages of the volume. His personal explorations within the State since the publication of the third volume had been but limited, most of his time having been occupied in the preliminary reconnoissance of the State of Arkansas, which his contract with the State of Kentucky permitted him to undertake. This recounts the various operations of the Survey, which are described in detail in the reports of the several assistants; and while quite brief, is full of very important suggestions concerning the economic geology of the State. It contains, among other things, a comparison between the Kentucky coal fields and those of Great Britain. While entirely disagreeing with Dr. Owen in his belief of the identity of the coal beds of our section with those of Great Britain, I am able, after a careful personal study of the coal districts of this country and of England, confidently to uphold his judgment as to the essential superiority of our coal areas to those of that country.

The unhappy death of Dr. Owen, hastened by his untiring and toilful devotion to his science, doubtless limited his contribution to this volume. Before his untimely death the whole of the work contained in this volume had received the benefit of his guidance.

The first of the assistants' reports is that of Dr. Robert Peter, showing the extension of the chemical work during the greater part of the two preceding years. Four hundred and twenty-nine analyses are reported here, of which one hundred and seventy-three are soils, one hundred iron ores, and thirty-six coals, representing a very remarkable body of chemical work. In the appendix we have a number of analyses of tobacco, made with a view to illustrate its influence on the soil, &c. The three hundred pages of these reports contain a record of

a great amount of patient, skillful labor, which only requires to be shaped to the present needs of the State, and collated with the other chemical work of the past and present Surveys, to make it an extremely valuable contribution to the development of the industries of the State.

Next after the report of Dr. Peter, we have from him a brief biography of the late principal geologist, giving the most important incidents of his social and scientific career. The paleontological report of Mr. Lesquereux occupies the next hundred pages. It gives a continuation of his important studies on the identification of the coal beds of Kentucky with those of other States, especially with the great typical beds of Pennsylvania. The whole of this report shows the marks of diligent labor in the collecting, and of great scientific acumen in the ordering, of its facts. At its close we have a number of careful descriptions of new species of fossil plants from the Kentucky coal measures. Unfortunately, all the plates which were to have been published therewith were never prepared, so that the scientific value of these descriptions is not what it should be.

We have next the report of Mr. Joseph Leslie on the results of his survey of the western outcrop of the eastern coal field, made in connection with the work done on the north and south base line, which was carried by him from the town of Grayson, in Carter county, to the Tennessee State line, by a survey made in 1858 and 1859. This line, like that from east to west above referred to, was intended as a determined basis on which to construct a series of maps which should in time come to include the whole State. At the same time it was made the means of determining the outcrop line of the eastern coal measures on their western face. Of all the field work of the Survey this proved, on the whole, the most satisfactory and important in its results. The valuable base-line map has never been published, and remains in the archives of the Survey; but the small sketch-map of the outcrop line is published with this report, together with the remarks of Mr. Leslie thereon. The geological part of this report, concern-

ing the place of the several coals, &c., has proved of much value in the development of the State; but it concerns only the outcrop line; and although the researches of the present Survey have shown its singular accuracy, when the time spent in preparation is considered, it will only serve as a valuable basis for the final work that is to be done. Of the value of the base line itself, more will be said hereafter.

The last report of this volume is from Sidney S. Lyon, topographical assistant, and contains a description of the work done in completing the east and west base line, and in continuing the work on the western coal fields by the survey of its eastern outcrop, and a detailed survey of Hancock county. This report contains only reconnoissance work along particular lines of travel. In no part is it sufficiently careful and detailed to enable it to rank as final work. The researches of the present Survey in the Greenup county district have shown it to be in error in many important regards concerning the rocks in that section. Much of this may doubtless be explained by the undeveloped character of the district at the time this reconnoissance was made; but the map, which was printed in Philadelphia, a sheet from an unfinished copper-plate, including what is now the county of Boyd and parts of the counties of Greenup, Carter, and Lawrence, is amenable to severe criticism, as will be seen hereafter.

It is very difficult to pass a proper judgment on the work done by the Geological Survey during the time it was under the direction of Dr. Owen. Working in the mineral districts of Kentucky, regions which to this day are to a great extent scarce-trodden wildernesses, there can be no doubt as to the great difficulties which beset its course. Considering the greater part of the work as a reconnoissance only, intended to find the paths along which the final work of the Survey should move, it may justly be awarded praise for the celerity and admirable accuracy of its determinations. The point where it fails is the common point of failure in all our State surveys—the topography. At the very outset of his work Dr. Owen showed a profound consciousness of the eminent need

of some map basis on which the record of the geology of the State could be laid down. With a view to serve as a foundation for this work, two base lines were run across the State, at the cost of many thousand dollars. These were designed for the basis of other surveys, which should give the State a map made on the general plan of the government land surveys which have been given to all the other western States, except those which were organized on the old territory of Virginia and North Carolina—although the prosecution of a topographical survey on this plan would have given a map of Kentucky, much better than anything we have at present, it would, at best, leave us where the States of the northwest are at present, with a map which is only a rude approximation to accuracy, and which must be done over from the very beginning before it can serve any of the important ends which would be served by a topographical map. In the method of making these base-line surveys we find much to criticise. The two elements of distance and direction, which need to be ascertained in such work, were determined in a merely approximative manner in these measurements. The direction of the lines was determined by compass-bearings, with no adequate correction for error, arising from the difference of variation at different points. No valid observations to determine the geodetic position of the points of termination of the line were ever made. The distances along the lines were chained through the woods, along a rude cutting. As in the east and west line, or in the case of the eastern, north and south line, the distances were taken by an odometer, where the revolutions of a wheel running along a road give a rude idea of distances—about as accurate as careful pacing will give. In this eastern work the precaution was taken to use a spirit-level to check the observations for level taken by a clinometer and barometer. In this way some exceedingly useful observations for heights were made; but for the strict purposes of base lines, these lines have so little value that it would be a great mistake to have founded any extended topographical work upon them.

The untimely death of Dr. Owen, followed by years of war, in which this State became one of the chief scenes of the struggle, put an end to the Survey, just at the time when its officers had acquired a true conception of the nature of the field and of the work required to discover all its resources. The destruction of the greater part of its records by fire, and the death of most of its assistants before the resumption of the Survey, has increased the difficulty of doing full justice to its work.

In a brief report of the operations of the Survey between the first of September, 1873, and the assembling of the Legislature in December of that year, I laid before the Governor the plan that had been adopted in the resumption of that work, as far as it had been possible to mature it in the brief time during which the task had been in hand. It is not necessary to repeat here all the considerations presented in that report; it may suffice to say, that the leading thought therein was, that the Survey should aim at thoroughness in its work, rather than at rapidity of execution; moreover, that the operations of the Survey should be directed not only to the immediate economic ends that it could be made to compass, but also to the object of extending the bounds of science as well. In it the ground was taken, that a great Commonwealth like Kentucky owes something to its name among States, and can best serve its interests by coöperating in the great work of advancing the standard of scientific learning, and by executing a public enterprise, such as its Survey, in the fashion that it will be helpful to this cause. At the same time it was proposed to make the main aims of the Survey tend directly towards the development of the industries of the State.

The obligations that were laid upon me by the act of 1873, and which were maintained by the later act, to continue the Survey of Dr. Owen, have to a certain extent determined the operations of the present Survey. I have felt it incumbent on me to take up the work left unfinished by Dr. Owen wherever I could find record evidence of his plans, and either carry the same to completion, or, as has in some cases proved neces-

sary, begin it again at the foundations. Acting on this plan, immediately on my taking up the duties of State Geologist, I went with my geological assistant, Mr. A. R. Crandall, to Greenup county, to examine the work which had been done by Dr. Owen's parties, under the immediate direction of Mr. Sidney S. Lyon, in that district. Since the abandonment of the Survey in this field, great changes had taken place therein. The statements made in that report had encouraged very considerable advances in the development of its mineral wealth; roads, railways, and furnaces had been built, and the opportunities for the study of the structure of the country very much increased. The first steps of an examination made it plain that, to do justice to this district, the geology would have to be done over again, with a view to secure more accuracy and a greater detail in the geological explorations, and generally to bring the description of the country nearer to the standard which should be kept in such work. As this geological work was carried on, it was found, to the great surprise and regret of the officers of the Survey, that the map of this section made in 1858–'9, on which the country is delineated with much detail, was so far incorrect that it could not be used for a guide or for the purposes of representing the geology of the country; therefore it was determined to have a careful review of the topography before publishing the report of the Survey. It being deemed best, however, not to undertake any considerable task until the Legislature had increased the first appropriation of ten thousand dollars by some further legislative action, the work during the autumn of 1873 was limited to a review of the geology of Greenup, Carter, Boyd, and a part of Lewis counties. In order to give a larger force to the work, the corps of the Survey, which in the original designation of the bill were limited to the principal geologist, chemical assistant, and geological assistant, was increased by the addition of another assistant, who should be specially charged with the duty of studying the iron ores and other furnace interests of the State; Mr. P. N. Moore, late an assistant in the Missouri Geological Survey, which had recently been suspended, a gen-

tleman specially trained for such work, was engaged for this duty, and began his labors in October, 1873. The researches in the chemical laboratory were resumed under the direction of Dr. Robert Peter, chemical assistant in the former Survey superintended by Dr. Owen. Dr. Peter's engagements as professor of chemistry in the State Agricultural College not making it possible for him to give his whole time to the work, Mr. John H. Talbutt, a competent chemist, was made second chemical assistant of the Survey. I count it a piece of peculiarly good fortune to have secured, through Dr. Peter, access to many of the traditions of the original Survey. In an effort to make the present work an effective continuation of that which has been done before, this has been a very great advantage. Until the action of the Legislature made it clear that the Survey was to be continued beyond the limits set by the first small appropriation, the work of this laboratory was limited to the analyses of those specimens which had been sent in from the assistants in the field. Special efforts were made to have these collections so made as to supplement the labors of former years. The newly opened mines and ore banks of Eastern Kentucky gave the laboratory work for some months. When the continuance of the Survey was secured, the available time of the laboratory, after the analyses in connection with the field work were done, was given to some special researches on various points of economic value to the State, as well as of much theoretical interest.

In the summer of 1874 Mr. Talbutt visited Grayson Springs to make a special study of the interesting group of springs found at that place. Some of the special points of this work will be found in a later section of this report. Dr. Peter has been specially engaged on an extensive series of analyses of the hemp plant, with a view to discover the best method of restoring the waste of hemp lands under cultivation. In order to facilitate this inquiry, and give an increased value to its results, it was deemed desirable to have certain special experiments in manures made on hemp fields. Greatly to the advantage of the investigation, Mr. Benjamin Peter kindly

offered to try these experiments on a selected field under his charge. These results will not be complete for a number of years, but the first experiences will be found in an appendix to this report.

Mr. Talbutt has also been employed in a special question of importance to the agricultural interests of our State. Our Kentucky crops are exceedingly wasteful to our soils, on account of the large amount of alkaline substances they remove from the soil and export to other regions. Especially is this the case with tobacco. The rapid impoverishment of our soils under the cultivation of this crop is a great danger to the State—probably the greatest it has to fear. It is with a view to investigate these evils that the Survey has been continuously seeking to discover among our rocks materials which could be used to advantage in restoring our wasted soils. This investigation should be extended over several years, and include the study of all our rocks which may appear to possess any advantages of this kind. Mr. Talbutt has given a good deal of time to the study of a set of beds, constituting what I have termed in these reports the Leitchfield marls, beds which are extensively developed throughout the whole of the western and a part of the eastern carboniferous or mountain limestone area. The results of his observations will be given in a report now in preparation. It appears from Mr. Talbutt's work that these beds contain a practically inexhaustible amount of potash and soda, which, with improved processes of extraction to which he is now giving his attention, may greatly aid the agriculture of our State, and afford a most valuable basis for a productive industry commanding a very wide market. With this same view, we have been extending our studies of the various beds which make up our blue limestones—the upper members of the Cincinnati Group.

A number of these beds have proved to contain a large amount of materials of value as manures, and several of them may well be used as means of bettering our high-priced lands. It seeming likely that some of the marly beds of this part of the geological section might afford a good material for paint,

a considerable number of analyses of the beds which seemed of sufficient promise have been made. The most satisfactory conditions seem to be found in the thick beds which lie near the top of the section at Frankfort, immediately below the beds characterized by an abundance of the *Strophomena alternata Raf.* These blue marl beds have a thickness of many feet, and several feet of the mass can be mined with great economy. It can easily be furnished by drift mining, at a cost not exceeding one dollar per ton for the crude material, and the cost of grinding is not very great. Then, these same beds are extremely developed at other points in the blue limestone district, though I know of no other point where they are, to the same extent, favored by good conditions for manufacture. The marls before referred to as the Leitchfield marls, belonging in the carboniferous limestone in the Western Kentucky coal field, seem also admirably adapted to this use. As it is in contemplation to prepare a special report on the material suitable for stone paints, I shall not discuss the question here in all its details.

In this connection it may well be noticed that the Survey is not forgetful of the important interests the State has in its building materials. Extensive collections were begun as soon as the Survey was assured of some permanence. They will be noticed at the close of this chapter.

In January, 1874, in order to increase the amount of work in the western part of the State, I made a preliminary reconnoissance along the line of the Elizabethtown and Paducah Railroad, and of the lead district in Caldwell and Livingston counties. As soon as a plan of work could be arranged, Mr. C. J. Norwood, formerly an assistant in the Missouri Geological Survey, was employed to take charge of work on the line of that road, and in the lead regions of the counties above mentioned. Mr. Charles Schenk, an able topographer, was authorized to take charge of the topography of the work. The design was to make a careful study of the coal, iron, timber, soil, and other resources of the region traversed by this railway, and opened by it to commerce. This work, with sundry

interruptions from difficulties of weather, &c., has been pushed forward to completion; and the first of its results, in Mr. Norwood's report, is now stereotyped, and copies are sent with this report. This Survey has given a statement which will serve to call attention to the very great resources of this district.

On the completion of this report, Mr. Norwood was able to take up his work on the lead mines of Western Kentucky. This work, of a reconnoissance character, has been completed. The results are given in Mr. Norwood's report, and it will be followed by a study of the lead resources of the rest of this district. In the spring of 1874 the parties were organized so as to place Mr. Crandall and Mr. Schenk in Eastern Kentucky, Mr. Crandall finishing the geology and Mr. Schenk the topography of Greenup district.

Mr. Schenk began his work on the Ohio river, at the junction of Lewis and Greenup counties, with the object of completing that angle of the published map of the old Survey. To review the map and add what had been omitted or incorrectly given, Mr. W. C. Mitchell, of Carter county, a gentleman personally familiar with this district by some years of surveying within its limits, was appointed assistant in the Survey, and began his operations with a full topographical corps in September, 1874. This work was continued until January, 1875, when the map was ready for reprinting. Mr. Schenk having completed the required work in the Greenup district, was transferred to Johnson county, and continued his work in that district until December, when the field work was discontinued. Mr. Crandall left the field in October, having completed a very thorough study of the geology of the counties of Greenup, Carter, Boyd, Lawrence, and a part of Johnson, with some reconnoissance work in Martin.

Mr. P. N. Moore finished his work in this district in the early part of June, and has since prepared his extended report on this iron district, which is published in the first volume of this series of reports. He was then transferred to the western district, and began the work in Edmonson county, which is

hereafter to be described. The Legislature having instructed me to organize three corps, if the resources of the Survey would admit it, operations in what may be called the central district were begun by a survey of the lead region of Henry and Owen counties. As a preliminary to this work, a topographical survey was begun by Mr. Page, topographical assistant, and Mr. Beckham, aid, with the intention of making an accurate contour map, on the scale of six inches to the mile. The greater part of this work has been completed, and the geological work as well, the latter by myself and Assistant Norwood. The completion of the map was necessarily deferred by the transfer of the topographical party to the western field. This suspension was caused by the impossibility of keeping three full topographical parties at work in the field on the exceedingly limited appropriation at the command of the Director of the Survey.

The interests of the great iron and coal region in Western Kentucky seemed to give it the preference when it came to be weighed with the limited resources of the central district; so, with the approval of the Governor, the change was made, with the belief that this would be found more to the interests of Central Kentucky than the work in Henry county. Work was begun in the spring of 1874 with by far the larger part of the forces of the Survey in the western district, besides Mr. Norwood on the Louisville, Paducah and Southwestern Railroad.

A large party was put in the little known coal and iron district of Edmonson, Grayson, and Butler counties. After some reconnoitering, hereafter to be described, I took charge of this party myself until Mr. Moore had completed his work in Eastern Kentucky. The party, as organized, contained Mr. Page, topographer; Mr. Procter and Mr. Beckham, aids, and Mr. Moore, geological assistant. In order to advance the work and give it more range, Mr. F. G. Sanborn, a distinguished naturalist, was employed as zoölogical assistant, and Professor John Hussey as botanical assistant. To this party was fortunately added Mr. Lucien Carr, assistant in ethnol-

ogy, who generously gave the State his valuable services in the study of its antiquities, without compensation other than the satisfaction derived from his interesting researches in the prehistoric remains of this region. Work was continued in this region until the following January, resulting in the completion of a map of all the coal and iron district between Bear Creek, the eastern border of this field, north of Green river and south of the Elizabethtown and Paducah Railroad, and east of Nolin river to the border of the coal field.

This extended and accurate map embraces about 400 square miles of very difficult topography, executed with extreme care and furnishing an accurate basis on which to lay down the geology and to construct public works. Mr. Moore, after completing the geological work on the district included in this map, was detached to make a careful study of the problem of the Airdrie Furnace. The unfortunate history of this furnace is given in detail in Mr. Moore's report; but I had become aware of the importance of the problem soon after beginning my studies in this field. In brief, the story is as follows: A great furnace, built at the cost of many thousand dollars, in order to use the "Black-band ore," a bed of iron ore occurring just at the top of one of our finest coals, had failed in its first weeks of trial, and, with all its great interests, had laid quite idle since 1858, given over to decay. It was evident that until this most untoward accident could be explained, it would be difficult to make a good showing for our Western Kentucky iron regions. I am glad to say that Mr. Moore's report quite confirmed the opinion I had formed from a preliminary examination of the region and the records, as it showed that there had never been any real trial of the furnace whatever; the first difficulties having resulted from an amazing combination of ignorance, carelessness, and the conceit of men who brought the prejudices of the iron trade of other countries to the work of our iron field.

I am satisfied that Mr. Moore's investigations, and the reports of the Survey on the iron resources which can be made available in the Green River valley, will do much to

make it the seat of an important iron industry as soon as the manufacturing interests of the country recover from their temporary depression. The researches of the Survey have distinctly shown that no other region in this or any other country, so far as known, possesses greater advantages for the cheap manufacturing and marketing of a high grade of iron. Other iron districts have, possibly, some slight advantages in the production of the metal, advantages that are more than neutralized by the considerably increased cost of marketing; but these ores lie on the banks of rivers communicating directly with the vast system of water transportation of the Mississippi, and with markets in St. Louis, Louisville, and Cincinnati—markets already with great demands, and which the natural growth of the country will, in a few decades, make the greatest in the world. This study of our iron resources in Western Kentucky will require some years for its completion, with all the force which can be spared from the Survey.

The work done in Edmonson county alone has shown the existence of a very extensive iron field, which can furnish exceedingly cheap, high-grade ores to a hundred furnaces for a century to come—their products being immediately accessible to water transportation with very slight improvements in the slack-water navigation of Green river and its tributaries, Nolin and Bear Creeks. A great deal was done to determine the relations of the various coal beds in Western Kentucky. This question is, however, so complicated that it will require several years of patient, difficult work to enable us to give a final and definite account of its resources. Every step we have taken towards this end has served to convince the officers of this Survey that the richness of this field has not been exaggerated. So great, however, is the amount of coal in the Mississippi Valley that it will be many years before a high degree of profit can be obtained from the ordinary qualities of coal. What should be especially sought, is to discover the special fitness of these coals for important manufacturing purposes. With this view I have endeavored to bring about careful trials of the coals for the manufacturing of iron, either

in the raw way or by means of coking the coal. It has also seemed to me very desirable to have trials of all our promising coals in the retorts of a gas-works.*

The same element of water transportation that gives such an especial value to our iron ores of Western Kentucky makes the admirable forest timber of that region a source of great possibilities in the way of manufacturing of various kinds. Mr. Hussey, botanical assistant, has made an extended examination of a considerable district in Western Kentucky with a view to showing the real value of these resources. The immediate accessibility of deep water throughout the greater part of the year in Western Kentucky gives it peculiar advantages as a place for ship-building industry. At present the whole forests of this region are disappearing before the advances of agricultural industry with little advantage to the people. Every effort should be made to give their riches a proper place before the world. It will be seen, I think, that Mr. Hussey's report is a step in the right direction, and should be followed by other reports of the same general character, until the whole of the timber resources of the State are properly exhibited.

The work of Mr. F. G. Sanborn, during the few months of his occupation with the Survey, was mainly given to the study of the caverns of the western district. This work has, from the first, commended itself to me, not only on account of its great scientific importance, which I hold in itself justifies its careful undertaking, but also on account of its considerable economic importance. The caverns of Kentucky are among the most remarkable curiosities of this continent. They must always arouse the liveliest interest, and bring many tourists to the State. When they are explored and mapped, and their wonders well set forth, they will become a great source of attraction to a much larger part of the world than has yet felt any interest in them. No other known region has a similarly extensive development of these caves. The Survey is also

* This is now under way at the Louisville Gas-works, through the favor of Dr. J. Lawrence Smith, president of the company.

getting data to determine their value for other uses. It seems likely that these caverns have a very great value for the storage of fruit and other perishable materials; the great uniformity of temperature, the dryness, the constant slight movement of the air, all combine to give a peculiar preservative influence. As the region where they occur is destined to be in close relations with many large cities, and is peculiarly suited to the growth of fruits and vegetables, there may be use for just these properties so common in our caverns.

In Edmonson county there are probably not less than five hundred of these caverns, of considerable size, and a careful search might develop more. Diamond Cave, the most beautiful cavern of the hundred or more I have visited in various parts of the world, was found by a mere accident, in making some excavations. Wherever a sink-hole occurs, it may be confidently stated there is a cavern of greater or less size beneath. The earth throughout at least six thousand square miles, in this part of the State, is quite honey-combed with these channels. Diligent search is likely to show tens of thousands of miles of underground space large enough to be passed by man. It is thus seen that if these caverns come to have a definite economic value, there is a sufficiently great area of them to serve all purposes.

The services of Mr. F. G. Sanborn, an able and distinguished naturalist, were for some months given to a special study of the caverns of the Edmonson district. The especial object was to examine into the character of their organic life, this being a question of very peculiar scientific interest, one that could not be omitted in our work. Dr. A. S. Packard also spent some time in the same inquiry. The result of this combined work of Dr. Packard and Mr. Sanborn will be discussed in the second part of this report. The object here is only to give some brief statements of its connection with the history of the Survey. The work of these gentlemen was limited to the spring and summer of 1874.

The act of 1874 required me to have an examination made into the fishes of our rivers. It hardly needs an argument to

show us that our food fishes are likely to become a most important element in the economy of the State. Kentucky is peculiarly a region of rivers. Within her limits we have not far from three hundred thousand acres of water area. It is estimated that each acre of well-stocked water is worth more than the best land as food-producing area. So that something like one hundred dollars per annum is assigned as the value of an acre of water for rearing good fish. From this, it is evident that in the future, when Kentucky becomes as densely peopled as its great mineral and agricultural resources make it certain it will be, the annual return from our fisheries may well rise into the tens of millions of dollars.

In order to lay the foundation for a thorough study of our fisheries, an arrangement was made with Mr. F. W. Putnam, a distinguished ichthyologist, to undertake the examinations of the fishes of the Green River system of streams. This work was begun in 1874 by a careful study of the fishes that could be collected in the neighborhood of the Mammoth Cave and on the waters of Nolin river. These collections were intended to be supplemented by others made on the lower waters of the stream, where we may expect another set of species from those which occur in the upper waters of the river. An unusually wet season made it impossible to do this work; so the report is necessarily retarded. Enough was done, however, to show the peculiar richness of this stream in indigenous fishes and its great fitness for fish culture. Nolin river has been the object of some studies of quite special character, with especial reference to its springs. It is evident that there are many springs along its course, where it passes through the carboniferous limestone, which could be utilized for trout culture. As will be seen from Mr. Page's report, one of these streams pours a volume of about two millions of gallons per diem of water, which does not vary perceptibly from 59° Farenheit, lying close to Louisville, and in a region otherwise well adapted for such work. There is no reason why this valley should not become an important region for pisciculture. These considerations

have distinctly pointed to the importance of making a careful list of the large springs within the State, and determining their actual flow and their temperature. If they can be brought into use, the value of a single spring may repay the cost of the whole investigation; for in the rearing of trout a spring may well be worth many thousands of dollars.

While the preparations for a detailed report of our fisheries will demand some years of labor, and should be the fruit of a special appropriation, there are some points to which I desire to call the attention of the Legislature, as they seem to show how wide and important the question really is. In the first place, I would call the attention of the Legislature to the fact that the food fishes of our rivers are not necessarily limited to those that live their whole lives and get all their food from these waters. Besides these groups, which unfortunately contain all the fishes at present found in our Kentucky rivers, we could have the forms found in other river systems, which have their birth in the smaller streams, pass out to the sea in their younger states, and do not return until they have gained, it may be, a hundred-fold in weight from their life in the great deep.

It is one of the most surprising results of observation in fishes that the individuals hatched in any stream, and going in their youth out to the sea, disappearing in its depths, reappear in the same stream when they come to lay their eggs, though several years may have passed away. In this way it is often possible to take from a given area of water at least one hundred times as much food as it would be possible to raise there if the fish had to be fed on the ground. These streams, then, become ways up which, each year, the sea sends some of its wealth of food far into the land.

With the warm and muddy waters of our western rivers, we cannot expect to succeed in naturalizing the Atlantic salmon, one of the noblest of our game fishes; but there is reason to hope that the shad can be made common in the Ohio; and in the California salmon, the Chinese salmon, and in several allied

forms from Europe, we may hope to find species of sea-ranging fishes which can be nursed in our rivers.

I have already arranged with the United States Fish Commissioner, Prof. Spencer F. Baird, who has kindly shown the friendliest interest in our betterment, to obtain a large supply of eggs of foreign species as soon as the State is ready to arrange for placing them in our streams, and the Legislature enacts laws for their preservation during the time when they are becoming acclimated.

The Geological Survey can only do incidental work in the furtherance of this great object, on account of its many duties. The State would do well to appoint a fish commissioner, and provide him with the means to make effective experiments. Five thousand dollars a year so expended would soon do all that is necessary to develop our fisheries. On one point, closely connected with the preservation of our fishes, however, I feel it necessary to speak a timely word. Cities are growing with rapidity along our streams. Their sewage and that of many detached factories is already beginning to defile our streams. I am personally familiar with the great evils which this system has brought about in England and other old countries, and with the means taken to obviate them. I am firmly convinced of the necessity of immediate action to prevent the extension of these bad effects of poisons thrown into our streams. Situated, as our cities all are, in positions where gravitation will do much to take the sewage on to arable land, they should all consider whether they cannot save the wealth which they are pouring into the sea in the shape of their sewage, the best fertilizer possible for land, for it contains the advantages of irrigation and manuring at the same time. There are at least half a dozen cities along the Ohio which now pour a great tide of poison into the river, not only making it a nasty sewer in low water, but also damaging the fisheries, and wasting the bread of the future at the same time.

In a low stage of water in June, 1874, I passed, in a skiff, from Newport to Louisville, desiring among other things to

see the state of the river in the summer season. This examination showed me that we were almost at the point where the pollution of the stream is becoming a serious danger to the health of the region, and is at the same time threatening us with the loss of its cleaner fishes. Another generation will add tenfold to these difficulties, and make it necessary for each State bordering on the Ohio river to join in some common means of protection to avoid making an open sewer of our beautiful river. Kentucky having the largest share of the Ohio river, more than half its area being within its borders, should take the lead in this very important work. If desired, I will make a careful study of this question and submit the results to the Legislature.

In this connection I may best notice the work done in the examination of the water-courses of the State by the Survey. This, during the year 1874, was limited to the study of the region covered by the topographical parties. Some mention of this work will be found in the topographical reports of the assistants; but it is proposed to retain the most of such matter until it can appear in a special report on this subject. A few general remarks may serve to indicate the state of the inquiry at the present time, and anticipate some of its results.

Throughout Kentucky the rainfall is equal to that of the countries most abounding in good water-powers. The range in amount is not well determined, but is probably from forty-five inches on the Ohio to about sixty-five inches in the Cumberland mountains. This is much more than falls in Massachusetts or the other New England States—regions of valuable water-powers. The amount of declivity down which it flows is equally satisfactory, being all-sufficient for the best uses of the water. The sites are unequaled. Nearly every stream has along its whole course rock bottom and rock sides within easy reach. The only difficulty lies in the amount of storage power of the earth and the irregular seasonal distribution of the rains. It should be noticed that when a rain falls on any great surface, the water may be divided into two bodies: the one finds its way directly to the streams without

entering the ground, the other finds its way to the streams through the slower channels in the soil. It is this last named water that gives an economic value to the streams; the first is hardly more than a damaging element, and may be called the flood-water.

In New England a soil resting on sand and gravel, a great system of ponds and lakes, and great areas of high-lying swamps, all serve to retain the greater part of the flood-water and to discharge it slowly. In Kentucky, as there has been no glacial action to make the gravel beds and upland swamps, we do not have this structure of soil, and all our spring or ground water, as we may call it, must come from the soil proper or the rock below. Art can do something to remedy this defect by making storage reservoirs to retain the flood-waters, and I look forward with confidence to this result. I shall have occasion to advert to this matter of storage reservoirs in another part of this report; but for the present it will suffice it to say, that permanent water-powers, without such reservoirs, are not possible in the smaller streams of the State, with the exception of those in the cavern district. It is not the least of the advantages of this district that the caverned rock makes a great storage for what would otherwise be flood-water. In this caverned section, as for instance in the case of Nolin river, we have streams relatively of great steadiness, and admirably adapted for great water-powers.

Nolin river will furnish a water-power comparable to many of the most important of the New England rivers. The report of Mr. Page will show that, in the extraordinary dry season of 1874, it, at the lowest stage, ran so as to be equal to twenty horse-power for each foot of fall, a quantity which probably much exceeded the discharge of the Licking river at the same time, though that river drains a district having an equal rainfall and some ten times the area of surface.

Green river itself, draining, as it does, a large cavern area, is capable of making an admirable water-power at almost any point above the slack-water navigation; and below that point, wherever there are dams, there are waterfalls of great steadi-

ness of volume, and of several hundred horse-power, at the lowest water, going to waste. I examined these dams at the lowest stage in many years, and am convinced that they may be relied on, at each dam, to run turbines up to three hundred horse-power, leaving lock water enough for all business that is likely to be brought to them.

The disadvantage which Kentucky water-powers generally have, in the small storage power of our soil, is somewhat compensated by the great freedom from ice. In this respect mills on the Green river will have peculiar advantages. On account of the cavern storage, the water in the stream is relatively much warmer in winter than the rivers of the most of the State. It is said that it often remains open after the Tennessee, whose waters course much further south, has been closed with ice.

Some difficulty will be met in our Kentucky streams on account of the frequency of floods; but, with the great advantages arising from good foundations and tide walls, this need not be very great. On the whole, the State may look to its water-powers as a valuable supplement to its more important source of power in its coal. I am satisfied that it will be wisdom to give these powers a thorough investigation.

In this connection I may say, that an important question now occupying the attention of the officers of the Survey, is that of water supply for the growing cities and manufactories of the State. In this, as in several other matters, the plan has been adopted, for which warrant will be found in the law of 1874, of writing letters to the journals likely to reach the people most interested, giving the facts which should be used in the guidance of engineering works looking to water supply. This present and growing need is one of the strongest arguments for effective legislation directed to the preservation of our rivers from the waste of our population and our manufactories. Over one seventh of the population of the State now depends on the Ohio river for the water used for domestic and manufacturing purposes. In a few years we may reckon that

this proportion will be materially increased. With the growth of the need, we are now getting a diminution of the supply by the progressive fouling of our streams. But two sources of water are offered us, our rivers and the water stored in our rocks—held there as in a sponge. Unfortunately the same circumstances which have filled our rocks with the elements which make a fertile soil and valuable mineral resources, have made the waters stored deep therein unsuitable for domestic purposes or for manufactures.

While it is a fact that the blue grass water, or the water from the limestones of the Cincinnati Group of rocks, has a peculiar fitness for the manufacture of the principal export of that section, it is also a fact that it is not possible to have it save at certain springs and wells of shallow depth. As soon as a well reaches below the drainage of the country it gives water charged with a large number of mineral substances, valuable for medical properties, but unfit for general use. It is only from the rocks above the drainage, where long continued leaching has worked out all these substances, that we can get water of reasonable purity. Our mineral resources are sure to create many great cities within the Commonwealth during the century to come. For these the water supply must be sought in our large streams. There is no other resource.

We may now return to the geology of the eastern field. With this year's work the parties of Mr. Crandall, Mr. Moore, Mr. Schenk, and Mr. Mitchell finished the work which is given in the reports of Messrs. Crandall and Moore and the maps of Messrs. Schenk and Mitchell. The economic results of this Survey cannot help being of some advantage to the State. It has shown the existence of a much larger mass of coal and iron than was supposed to exist in this district. The demonstrations of the existence of the upper limestone ore over the large area it has been shown to occupy is a matter of great consequence to the State. This ore is the largest single element in the success of the Hanging Rock iron district. In the four counties included in this field, we have demonstrated

the existence of a sufficient area of this ore to occupy many times the present number of furnaces in the district for centuries to come. Along with the important series of ores which have been studied in detail, as will be seen from these reports, we have a coal that is known as the Ashland or Coalton coal, which is one of the few coals in the world which can be advantageously used in its raw or uncoked state for the making of iron. In this coal alone this region has the assured basis for a great industry, and the Survey has been able to show its existence over a wide field.

The reconnoissance of the Survey, which has extended beyond its final work in this direction, leads us to hope for a considerable southward extension for these two valuable resources of coal and iron of known qualities. Mr. Crandall's studies on the timber lands of Eastern Kentucky will, I am inclined to think, be found of peculiar value. This method of measuring the timber of a country is now first used in this report. No little consideration has been given to this matter of investigating forests, and the most considerable difficulty has been to find a way of recording the character of its timbering, the size of the trees, their relative numbers, &c. This difficulty has, I believe, been met in this plan of counting the trees on given areas and determining their size, height, &c. I must call especial attention to the recommendations made in that report as to the preservation of our mountain forests and their maintenance as sources of production of timber. This source of wealth is rapidly growing in price, and as that country becomes the seat of great industries, the capacity for producing good qualities of hard-wood timber will be a great advantage to its other interests.

To complete the brief notice of the operations of the Survey during 1874, I must now speak of my own work during that time. A very large part of the time of the superintendent of a survey, where there are many workers, is necessarily taken up with the work of mere direction. I was compelled to make several journeys to the eastern field and several to the western. Moreover, the correspondence connected with

the bank, which generally occurs by their broken branches drifting by and becoming accidentally fixed, they grow with great rapidity, spreading in every direction by their branches becoming buried by successive floods, and sending fresh tops from every bud. Very soon there is a little grove formed, it may be some hundred feet or more from the retreating bank. This thicket, when floods come, bends to them, but its interlaced branches form a little dead water, in which the coarser sediment carried by the stream sinks down; masses of drift-wood often tangles in the branches and aid this process; but practically it is slackened current, and the consequent deposition of sediment, that causes the accumulation. After some of the heavier floods there will be as much as a foot of mud laid down on these willow thickets, and in some cases I have seen this mud coating extend half a mile along the river; not only within the space occupied by the young wood, but for some distance below its lower end.

Unlike most trees, the willow, and, to a certain extent, the cottonwood, have the power of sending out roots from any point on their stems or branches. The result is, that generally before the next flood this mud is woven through and through with fine roots, which bind it all together. The gain from this process is often singularly great, keeping pace with the growth of the swift increasing trees. At many points it is evident that the gain is at the very point where decay was the most rapid before the willows got hold. With what is relatively a very rapid rate of change, this new-made ground rises until it comes to the level of the ordinary floods, then more slowly until it gets to the point where the highest floods alone touch its surface. In ten years, it sometimes happens, the land is high enough to cause it to become arable land, yielding the richest crops. At a point near Galipolis, on the upper Ohio, a skillful farmer has planted the whole front of his extensive farm with these willows. From a wasting bank it has come to make constant gains on the river, until in ten years he has recovered several acres to cultivation. At some other points less extensive plantations have been made, always with the

same substantial result — a gain on the stream. These instances of successful plantations of willows, show that there is no difference in the essential result, whether these plantations are made by nature or by art. The question at once arises, whether the river cannot be controlled in its changes, and the lost ground recovered, by making plantations along the whole of its shores where there is risk of wear, or where it is desirable to regain lost ground. I believe I am safe in asserting that this is quite practicable without any considerable expenditure.* Those who have made plantations tell me that they reckon the cost at a rate which cannot exceed one hundred and fifty dollars per mile of front, or, at the most, three hundred dollars for each mile in length of the river, counting both sides. Twigs or cuttings of the willow, from two to four feet long, of any size, holes made with a bar of iron, and the cutting fixed by pressing the clay around it; this is all that is necessary for the planting. Planted in the spring, the roots make the cuttings secure before the autumn floods can endanger them. I am satisfied that the good effects of this process on the river will become evident within ten years after a general planting, and that a large part of the waste, that has taken place within the century, will be slowly regained. As Kentucky has more than half the length of the Ohio within her borders, and as the larger part of its tributaries cross her soil, it properly falls to her to take the lead in the study of the Ohio system of rivers, and the correction of the evils which come from the want of regulation of their flow. Having been for many years a student of this river, I have, from the beginning of the Survey, done all that could be done, incidentally, to study its peculiarities, and to contrive ways to overcome some of the dangers which menace the river and the country through which it flows. This work will be continued in the future, if the Survey is maintained. The plan proposed by Mr. Ellett, many years ago, of restraining the violence of the Ohio floods by holding back some of the flood waters which make our annual inundations, and using

*I proposed this plan in the autumn of 1873 in a letter to the Frankfort Yeoman.

them to mitigate the summer seasons of low water, has never received adequate attention. The summer of 1875 brought more to mind the great dangers of these floods, and added to their terrors, inasmuch as it showed that they may not always come during the winter season, when the crops are all harvested, but they may also occur in the time of growing, when they cause a peculiar destruction.

The floods of July, 1875, it is estimated, swept some ten million of dollars' worth of crops and other valuables from the borders of the Ohio valley streams. This damage, added to that done by the floods of the other parts of the country, aggregates probably not less than twenty million of dollars for the year 1875, the very interest of which represents a formidable sum. With each succeeding year of increased forest clearing this danger augments, and unless something is done, we may reckon on far more sweeping floods, acting upon a more and more densely peopled region.

The scheme proposed by Mr. Ellett has been rather hastily condemned: it was in substance a plan to keep back the flood waters by great dams, creating reservoirs on the head waters. It has been argued with some force that it would be impossible to retain enough of the floods materially to affect the inundations of the Mississippi in any limited number of reservoirs, without requiring works of a peculiar magnitude. Ellett's proposition was open to the objection that it did not bring the question in a practicable form; but from a considerable study of the matter in the field I am inclined to think, that while these objections lie against a limited number of reservoirs of great size, they are not necessarily fatal to the general plan of retaining flood waters by a system of very numerous small reservoirs placed in the head-water region of each of the main tributaries. I am satisfied, from a preliminary study, that it is likely that in the case of a stream like the Big Sandy or Chatterawah river it will be possible to keep its floods within bounds by a system of small reservoirs, about one thousand in number, costing, on the average, probably not exceeding two thousand dollars each for their construction, and not over an

average of fifty dollars per annum for their maintenance and repairs. These dams, I estimate, would contain an amount of water represented by the upper ten feet of flood tide at Cincinnati during one day, which is the most destructive part of the height. About four times as much retaining capacity as is obtainable in the valley of the Big Sandy would take by far the larger part of the destroying power from the Ohio floods, for it is the upper ten feet of their rise that brings nearly all the devastation. These small mountain ponds would not destroy much arable land, and the damage they would do in this way to the productive land of a county would be more than compensated by the value they would have for irrigation purposes. Moreover, by giving mill powers and a certainty of a supply of water in the stream below, they would far more than compensate for the damage they would do by diminishing the area of timbered and arable land. The total area occupied by these ponds would be not far from fifty square miles in a valley the size of the Big Sandy—only about one one hundredth of its total surface. The discharge of these reservoirs could be managed by means of a waste pipe, which should automatically empty the pond in say sixty days, or it could be controlled by local superintendents, acting by telegraphic orders, which could come from some general supervisor in communication with the Federal signal service system. At the present time these considerations may seem utopian, but it is the duty of the student of economic geology to look forward to the result of changes now in operation, and to give warning of the dangers which may be apprehended from them.

The unexcelled resources of Kentucky, combining as they do a rare fertility of soil with a very rich store of the minerals which form the largest basis for industry—coal and iron—makes her surer of a dense population than any other part of the United States. We must watch all the dangers which will come from a rapid increase of population, and the consequent disturbance of the old relations of the forces of nature.

One of the most prominent features of this district is the large rainfall and the frequent occurrence of a great deposition of water over all the tributaries of the Ohio and the Mississippi. Each new cleared area increases the suddenness of the floods and protracts the times of drought.

Besides the special effect upon floods and low water that may be hoped from the retaining a part of the winter rains in the country, there would be several contingent advantages worthy of mention. Among these I have already incidentally mentioned the irrigation facilities they would furnish. This is a matter of much consequence in the future of our agriculture. Whenever there is a summer of great heat the productiveness of a soil can be more than doubled for most crops, and quadrupled for others, by the use of this means of providing against the consequences of droughts. Within fifty years this method of fostering crops will be made an important element in the agriculture of this country. On the usual basis of calculation, the given area of reservoirs in the Big Sandy valley would serve as irrigation supply for about one thousand square miles. A greater immediate gain would be found in the increased flow of waters in our rivers, thus aiding the navigation, and giving a greater value to the mill powers on their waters. Incidental advantages would doubtless be derived from the effect upon the climate and rainfall of the country. It is probable that a noticeable effect on the intensity of both heat and cold would be felt in case this plan of storage reservoirs was ever generally adopted in the Ohio valley. Masses of water are the natural balance wheels of temperature, and the effect of even small areas is always perceptible in their immediate neighborhood. A striking case of this action is seen along the shores of Lake Erie, where the climate is greatly mitigated by the presence of the lake.

In order to have efficiency, the control of the water system of the Ohio valley should come into the hands of the Federal Government. Any other method of control will require a close coöperation of effort in several States, which presumably can-

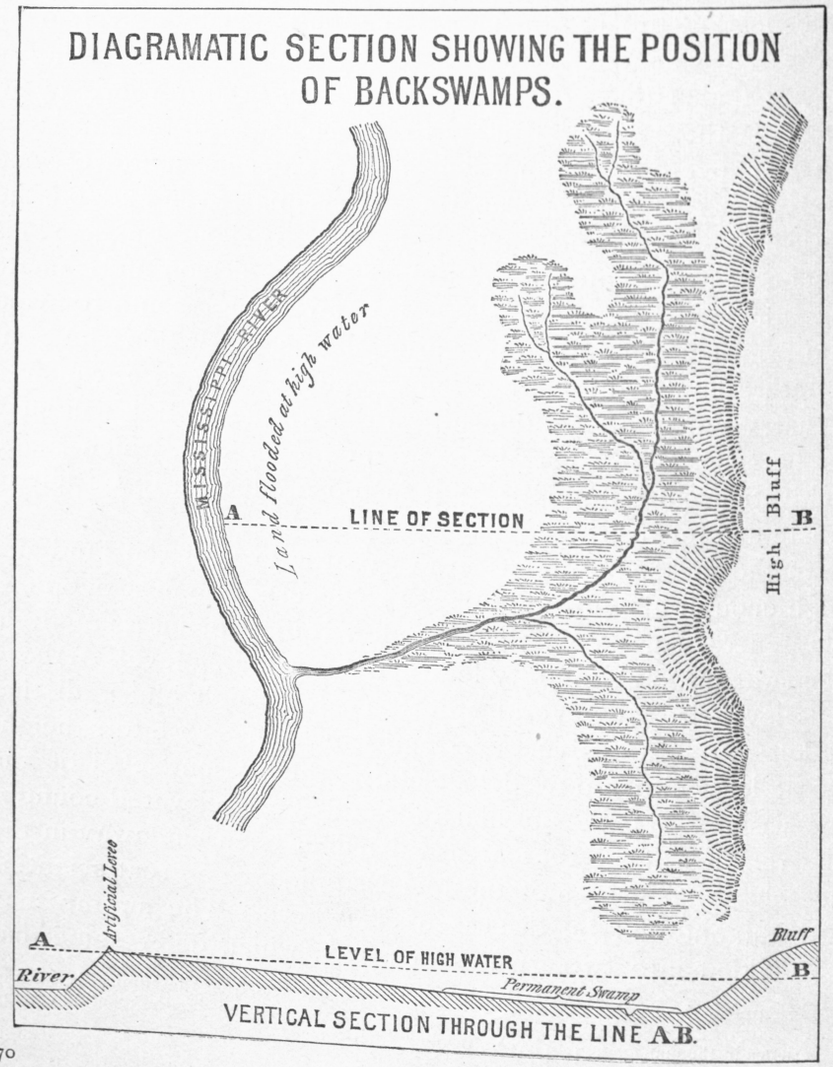
not be effectively secured. Yet this Commonwealth, being interested, above all her neighbors, in the work, should take the lead in bringing about some effective action.*

In July, 1874, taking advantage of the low water of the streams, which made the swamp region of Western Kentucky bare of water, I made an extended journey in the Jackson Purchase, with a view of ascertaining what are the possibilities of benefiting the region liable to inundation by a system of levees. Incidentally I desired also to see the resources in the way of timber that country affords. This region where, by all accounts, there seemed likely to be a chance to reclaim large areas of overflowed land, lies in the extreme southwest end of Kentucky, bordering on the Mississippi river and on the series of swamps and ponds known as Reelfoot Lake. This region lies in a zone where the conditions of soil and climate give the land a peculiar value. It is far enough south to avoid the principal dangers from spring frosts, yet within the temperature limits where white labor can be used to advantage. Whatever may be the difficulties, this fertile section will have to be secured against the continued overflows, which make cultivation quite impossible; it is too productive to be left to waste and fever-breeding.

In the Jackson Purchase the greater part of the land lies high enough above the drainage to secure it against overflow. Its general surface is that of a low rolling plain, rising from the swamps to about fifty feet above the water level. Above this level rise, at several points, a set of high bluffs, all that is left of an extensive table land which once rose to a height of at least two hundred feet above the present level of the Mississippi. These singular relics of an old elevated country, the remains of a great area which has been cut away in the ceaseless wanderings of the Mississippi, have a great scientific interest, and will be discussed elsewhere. The swamp may be divided into two groups of areas, which differ somewhat

*In Appendix A to this report I have made some extracts from the admirable work of G. P. Marsh, "The Earth as Modified by Human Action." They give the results of man's experience in the management of rivers in older civilizations.

in their character and much in the method of treatment which may be applied to their redemption. Of these we will consider, first, what may be termed the *back swamps*—we shall call them by this name—which are in fact within the range of the pendulum-like swings of the rivers. The accompanying diagram will make their conditions more easily understood:



By the figure and explanations it will be seen, that as the river gradually abandons any one part of its course by cutting away the bank on the opposite side, the abandoned part gradually, by the silting action of the river, rises to the level of the highest floods. At low water, as soon as it gets to the surface, a mat of thick vegetation forms upon it, and in its meshes the deposition of silt becomes very rapid. Whenever the river remains stationary for awhile, this action, due to the stoppage of the current, builds a sloping rampart from the river to the swamp. When the river overflows the greater part of the mud falls down near the bank, and only a small part finds its way back into the swamp, where the currents of water are relatively very slow moving, and carry only little silt. If it were not for the timber the water would move more freely through these swamps, and the deposit within them would be much more considerable than it is at present. The diagram and explanation is designed especially for the Mississippi swamp, but it applies, in a varying degree, to all the border, swamp, and intervale lands along the bayous and streams wherever the deposit of silt is going on. Generally, however, the side streams have this feature in a far less marked form than along the main river. Thus the difference between the land along the main stream and the swamps inclosed by it may be twelve feet or more, probably attaining, at some points, more than twenty feet. If we turn from the main stream and follow up any of the tributary streams towards its head, we find that the amount of the deposit bordering their banks and the height of these banks above the swamp grows less and less, until the height of the natural levee is not over one or two feet. This shows the fundamental difficulty of managing the levee system. Either we must close the gates of all the creeks and hold their flood waters in, until the main stream has gone down, or we must carry levees of great height back along these streams, from the shore levee to the high country, which may lie miles from the bank.

I am inclined to think, after a comparison of these conditions with those of Holland, with which country I have some

personal familiarity, that the inclosing of the whole area by an artificial levee carried along the top of the natural rampart bordering the main stream, with flood-gates at the passage of the tributary streams, will be the easiest way of solving the difficulty. Allowing for the heaviest rainfall that ever occurs in this country, say fifteen inches in a month, the included swamps should be able to store two months' water without rising more than four feet. When, in the course of one or two generations, the land becomes of sufficient value, this variation in the waters of the swamps can be still further limited by the Holland system of pumping by wind-mills or by mills driven by the river current. But a simple dyke system can be introduced at small cost, provided the surveys demonstrate the practicability of what seems quite practicable from a reconnoissance.

There can be no doubt that the fevers that trouble this swamp region will diminish in proportion to the restriction of the limits of the rise and fall of the floods. The experience of Holland shows conclusively that the institution of a permanent water level is the one effective bar to the production of malaria.

To give an accurate basis for so considerable an engineering work, one which would relieve a district of great natural fertility of over a thousand square miles of its disabilities, it will be necessary to have a tolerably detailed survey, to ascertain the amount of swamp land and of upland drainage in the drainage areas of the streams that flow into the Mississippi and the Ohio from this overflow belt, and to ascertain the precise levels along the stream banks. With this there should be combined a careful study of the rainfall, extending over a series of years, and taken at several points in the district, so as to obtain average results. This work is to be a part of the labors of the Geological Survey for the future, if its continuance is assured.

There is one point in this district where the conditions are peculiarly favorable for the recovery of a large area of arable land. I refer to the vicinity of Reelfoot Lake. Coöpera-

tion with the State of Tennessee should be secured, for part of the work has to be done in that State; but the physical conditions are quite simple. It is known, doubtless, to the reader that this area, already low land in the first exploration of the country, sunk much below its original level during that memorable convulsion, the earthquakes of 1811–'13. The depression seems to have lowered the level of some fifty square miles of land, so that it lies permanently below the general level of the drainage. Around its shores we have a vast extent of fertile fields, capable of the highest culture, but for the frequent floods of the spring-time. A levee along the Mississippi bank of no great height, and a flood-gate at the passage of the lake into the river, would secure this region against inundation, provided, as I believe is the case, the storage capacity of the lake is great enough to retain the water of the drainage area for two months. This can be ascertained by a survey without much cost; but it lies in part beyond the State of Kentucky, and should be the result of some coöperation between our Commonwealth and the State of Tennessee, or the Geological Survey should be expressly charged to carry the Survey beyond our own bounds to complete any necessary work. If a system of levees is applied here the land recovered cannot fail to play an important part in the resources of the State. It is peculiarly fitted, by climate, character, and position, for field and garden purposes. Immense crops of corn can be raised on it, and it is peculiarly suited for early vegetables of various kinds. The river affords transportation for such garden products, being less than a day from the St. Louis market, and by rail only a short distance from the many cities of the northern part of the Mississippi valley. I am inclined to think that there is an admirable field in the immediate future for the investment of capital in the subjugation of the upper levels of the swamps in this section.

In passing I cannot forbear to call attention to the remarkably picturesque features of this singular lake region. Approaching it from the only convenient point, Hickman, the traveler passes along the crest or at the base of the Chicka-

saw Bluffs for some ten miles of distance. Taking his way along the crest of this remarkable bluff region, he sees a great stretch of the ancient upland, which has been torn to pieces by the unending war of the river. On the river side the bluff is an almost precipitous face, densely timbered, beyond which the eye ranges over the vast sombre forests which fill the Mississippi valley. At the end of the bluffs we descend to the level of the low plains which constitute the upper swamp, and soon a little further descent brings us into the dark cypress woods of the lower swamp levels. Little by little the water increases and the solid land grows less, until the woods break away and the traveler looks off on to the singular lake, unlike any other lake in the world. The cypress trees which covered the old swamp were killed when the ten feet of earthquake-sinking brought their roots permanently below the water; for this tree, like all others, must have a part of its roots above the water level. The knees, at least, must lift members above water or the tree dies. When these grand forests perished the trees were left, their roots preserved from decay by the water which covered them, their tops dropping slowly to decay. Some twenty-five or thirty years ago a fire spread from the shore through their branches, stripping the trunks and leaving them blackened obelisks of fantastic forms rising often near a hundred feet above the lake. The lake itself seems a vast undetermined network of water paths, fairly blocked with a tropical growth of plants, stretching as in a maze among these seemingly limitless columns of this ancient forest. Several species of lily-like plants flourish here, among them the *Nymphea odorata* of gigantic size, with flowers often eight inches over. In July the great chinquapin lily, or *Nelumbium*, is in bloom. No other North American flower approaches it in gorgeous beauty. The corolla, a great yellow lily-like cup, often a foot across the rim, is borne on a stem three feet above the water; on either side two leaf stems lift into the air leaves which are over two feet in diameter; the other leaves float in the water around these elevated stems. There is a great abundance of other water

plants, the whole making a mat of foliage dense as a carpet, which can only be penetrated in certain channels. The lake is richly stocked with fish, affording, it is said, great sport, especially in the winter season. This whole region was a favorite fishing ground of the Chickasaw Indians, who were essentially a fishing race. They used the seed of the chinquapin lily for food. This plant is, practically, identical with the lotus of the Nile, so that this people may be said to have been a race of American lotus eaters.

I most strongly commend this region to those of our citizens who admire the beautiful in nature. In either its winter or its summer aspect, it affords a most remarkable and attractive scene.

I have incidentally referred to the magnitude of the cypress forests in this section. This wood, now nearly neglected, is destined to become one of the most important elements of wealth to the region where it abounds. Although not, on the whole, as valuable as the pine, for most uses, it still must be counted one of the most important of our American soft woods. It attains very great size, is remarkably free from blemishes, and can be worked with ease. It occupies a very large area in the Mississippi valley, a great part of which is now regarded as valueless. As our pine forests diminish, these cypress swamps will yield a larger and larger part of the soft wood of the country. The region where it abounds covers, perhaps, a larger area than all the untouched accessible pine forests of this country. The country producing this species of tree is well intersected by streams and is all flooded with navigable water at certain seasons, so the transportation is not wanting. Moreover, the forests seem to renew themselves with rapidity, so that we may look forward to our swamp areas as the source of production for a valuable element in our future industries.

With reference to the improvement of the navigation of our rivers, and the making navigable of many streams not at present regarded as fit for any material use, I have from the first entertained very decided convictions. The most prominent

feature in the structure of Kentucky, and her strongest hold on the commerce of the country, comes from her wonderful river system. In order to become personally acquainted with the needs of this system, I have made several journeys along the courses of some of the principal tributaries of the Ohio. In August of this year I made, with Assistant A. R. Crandall, a journey up the Big Sandy, with this for one of my principal objects; the other was to extend our general knowledge of the eastern coal field. In passing from Riverton over into the valley of the Big Sandy we found one of those curious changes which so often occur in our coal-bearing rocks, where the passage from one valley to the other is accompanied by very great alteration of the character of the coals and their associated rocks. We seem to pass beyond the region where the Coalton coal was well developed and the iron ores, which give so important a character to the valley of the Little Sandy, also disappear, or are greatly reduced in number and altered in quality. Other coals, and probably other ores, which in some cases were hardly marked at all in the Little Sandy, come to take the first place in this valley. The change is so great that it is not easy for the geologist to make quite sure of the identity of the beds in the two sections. A little doubt remains over the determinations, but I agree with Mr. Crandall in thinking that the very important bed of the Peach Orchard coal represents the Turkey bed coal of his section in Carter county. This will make the whole of the section in the valley of this river a little higher up above the sea than the beds on the Little Sandy. Notwithstanding the change in the character of the beds, the valley of the Big Sandy seems to promise quite as well for yield of coal as the region to the east. No effort having been made to develop the iron ores, the means of ascertaining their actual value have been poor. The valuable upper limestone ore seems to have disappeared with the disappearance of the limestone which underlies it. The main limestone ore is buried beneath the level of the drainage of the country. A massive and somewhat promising ore occurs near Peach Orchard; but all the specimens seen

are so full of pebbles that they could not be regarded as fit for furnace use. It is likely that this feature is rather local in its character, and the bed may, on proper search, be found free enough from this matter to pay for working.

As we pass up the river other beds of coal come into prominence. At Prestonsburg a coal, probably answering to No. 4 of the Greenup district, is seen, with the details given in the report of Mr. Crandall. Some coal has been taken from this pit, and it is probably the same as that which was once worked further up the river, and furnished a coal of an admirable quality, that sold above any other coal in the Ohio valley in the Cincinnati market.

At this point our route left the main valley and followed the course of Fur Creek. On this stream we found no coal open; but there are what seem to be trustworthy reports of at least one bed of satisfactory thickness. This is reported by Mr. Evan Jones, of Prestonsburg, a skilled English miner, and a trustworthy person, as being over four feet thick. The openings had been closed by timbers, so that the section could not be obtained at the time of our visit. The general character of the section continues the same as along the lower part of the Big Sandy, so that we may expect to have essentially the same section as is obtained there. The indications of iron ore are, unfortunately, not more promising than in the region below; but I must again repeat, that iron ores are not necessarily conspicuous, and nothing but careful prospecting will do anything towards determining the actual value of the iron resources of the country. There can be no doubt of the existence of one or more seams of coal of excellent quality and workable thickness throughout this valley. At some points as many as three well-conditioned seams may be depended on; but for all purposes of the industries of this and the coming century one good seam of coal is all that is necessary. On the Tug Fork of Sandy there seems to be a material thickening of the coals, and a better average section than on the main stream. In fact, the main Big Sandy seems to be on a dividing ridge, separating the somewhat localized basin

of the Greenup district from the great Virginia coal field. The general character of the valley, the disposition of the hills and valleys, greatly favors the utilization of the coal contained in them. There are a great number of branch valleys leading from the main stream, and these have many minor branches, so that the surface of the country is cut into pyramidal masses, giving ready access to the coal and excellent ventilation and drainage. The general quality of this coal is excellent. It is my own belief that it is fully as good a coal for all the ordinary market purposes as that from the Youghiogheny valley, which now makes the market of the Ohio basin.

The timber resources of this valley are admirable, though a good deal of valuable timber has been taken from its various streams, especially from Bear Creek. The main supply has not yet been touched. Probably not over the one hundredth part of the timber has yet been marketed, and the growth nearly replaces the waste. Owing to the fact that not over one tenth of the land here is, by its shape, well fitted for agricultural purposes, it may be safely reckoned that, besides its mineral stores, the principal shipment from this valley will be the timber and articles made therefrom. By the position and the character of its wood it is peculiarly suited to be the source of timber supply for the lower Ohio. The reader is referred to Mr. A. R. Crandall's report for an account of the timber of this valley; for, although that account is framed for the valley of the Little Sandy, the statements will apply to this valley as well. The whole range of our hard woods is admirably represented in this section. The more valuable woods, the black walnut, hickory, and white oak, are relatively abundant on the upper waters of the smaller streams which I have visited.

The question of the improvement of this stream, and the means necessary to effect the same, have received much consideration from me. In January, 1875, I made to the chief of engineers of the United States army, through Mr. J. C. Bell, engineer in charge of the surveys in this valley, a report on

its resources, with reference to the desirability of bettering the navigation of the stream by a system of locks and dams. This report was sought from the Geological Survey by the engineer corps to accompany the report of the survey of the stream made during 1873–'4. After proper surveys, I believe that the Federal Government will take this stream in hand as a means of promoting that commerce between the States which the Federal compact puts under its especial care. I trust this very important matter will receive the earnest attention of the representatives from Kentucky.

The general conditions of the stream, as far as they bear on the question of slack-water navigation, are as follows: The river has sufficient volume for the navigation of boats of any size that the locks may be built to pass. There is at all seasons water enough for lockage. The bottom gives at all necessary points firm rock foundation for the structures, and the adjoining hills afford good building stone. The only difficulty that suggests itself is the securing of the extremities of the dams on either shore. This can be accomplished by means of rip-rap stone work, for which an abundance of material is at hand. I would also suggest that the points selected for building should be thickly planted with willows and cottonwoods, so that the earth be well bound together by their roots, and thus secured against the tremendous floods which sweep down this valley. These inundations are, relatively, the greatest of any of the tributaries of the Ohio. The Big Sandy has the peculiarity of being a stream with many divergent branches of large size and rapid fall pouring their waters together. The waters of these streams are gathered in a region, every part of which is formed by steep ridges sloping to the smaller streams, with declivities like house-roofs in steepness. The soil is not deep and the rock is rather impervious to water. The only springs are small and uncertain. But for the forests the water would be discharged in such volume that the valley would be swept clear of all its contents and made a waste from hill to hill. The terrible inundations to which the Garonne and other French rivers are, from time to time, subjected will give some

idea of the dangers which menace this country if it is ever stripped of its timber without compensation in the shape of a system of reservoirs capable of retaining a part of the floods in the hills, and of discharging the water, somewhat slowly, to the main river. This country is peculiarly well fitted for the construction of such storage reservoirs, provided the plan looks to the erection of many small ponds rather than a few very large basins. The streams generally are in flat valleys inclosed within boundaries of high hills. Good stone, clay, and timber are on the ground, and the land damages would not exceed an average of about three dollars per acre, which would be a small matter in a national work of this importance.

From the head of Bear Fork of Sandy I crossed to the waters of the Kentucky. The dividing ridges are not materially higher than the general level of the country in the Big Sandy valley, there being as yet no distinct trace of the disturbances of the Alleghenies. There is still on both sides of the divide the same abundance of the valuable hard wood timber observed below. Walnuts are more abundant here than at any other point I have yet seen, but no valuable amount of pine was observed. The Kentucky river at Whitesburg retains sufficient size and has the general character of channel necessary to make it susceptible of improvement by slack-water navigation. The valley is, on the whole, wider than that of the upper branches of the Big Sandy, and may be deemed well suited for the passage of a railway. A general account of the coals of this section will be found in the report of a reconnoissance by Mr. P. N. Moore and also in the original reconnoissances of Dr. Owen's Survey. I must, however, repeat the caution, that a reconnoissance of a country where the coals or ores have not been the objects of search on the part of the people, is not likely to develop more than a small fraction of these resources. Coal beds are particularly liable to escape observation. Decay causes them generally to retreat further into the hill than the other beds of the section. The face is then covered by the waste from above, and in this

position a considerable coal bed may remain for a long time unnoticed, until some accidental excavation discloses it.

The admirable character of the timber observed in the Big Sandy district is maintained in this valley. Walnut timber of good dimensions abounds, and will furnish a considerable export as soon as an available means of transportation is provided.

The upper waters of the Kentucky seem to have a much steadier flow than those of the western branches of the Big Sandy. This is in a good part due to the fact that its branches arise in a set of rocks which make much better reservoirs of water than any drained by the Big Sandy. Pine Mountain, which furnishes the headwaters of almost all the streams which fall into the Kentucky above Whitesburg, is, in the main, composed of conglomerate and limestone, and has good water storage capacity. At Pine Mountain, which we struck about five miles south of Whitesburg, we come in contact with the westernmost of the distinct mountain ridges which constitute the Alleghenies. Ascending a steep path we cross in succession a series of rocks, which, though covered at their base, must give us, above the water level, beds all the way from the rocks which immediately overlie the Cincinnati blue limestone up to the coal measures. This elevation of the lower beds is accomplished by a great break in the rocks, those on the west side keeping their place, while those on the east have been lifted nearly a thousand feet—a distance about equal to the height of the mountain. The scientific value of this break will be adverted to in the next section of this report. For our present purpose we are concerned with its economic importance alone. Besides the considerable gain to the water supply which comes from this mountain, we have to notice the importance of the bearing of the subcarboniferous limestone. This secures to this district an ample source of supply of a limestone suitable for building purposes, mortars, &c. It also furnishes an abundant source of supply for agricultural purposes to a district where the first source of impoverishment will always be from the loss of the

lime in a soil where this element is the first to become deficient. In case of the discovery of available iron ores in this district, this limestone would also have especial value as a flux, for which it has always been found well fitted. In a subsequent part of this report it will be noticed that the probability of the occurrence of the Clinton iron ore in this district is discussed in connection with the occurrence of these deposits near Cumberland Gap. It is enough to remark here, that there is a great probability of the occurrence of these beds at some point above the drainage level along Pine Mountain, though it will probably be many years before the deposits will be available, there being a large district where they are of much readier access.

Descending Pine Mountain into the valley of Poor Fork of Cumberland river, we find ourselves again in the carboniferous beds. This region is so closed in by mountains that its coals are probably destined to long remain untouched for any save local uses. There is evidence of some exceedingly good coals in this valley, exceeding in their thickness anything observed on the western side of the Pine Mountain. The most promising bed has not been opened so as to show its character. See the report of N. S. Shaler, A. R. Crandall, and P. N. Moore on this district hereafter to be published.

The valley here has an entirely different character from those of the other Kentucky streams. They generally run through cañons where the only shaping agent has been the water, and all its hills are caused by its action. Here, however, the Pine Mountain on the west and the border of the anticlinal, a variously-named ridge which forms the boundary of Kentucky on the east, bound a valley of great width and beauty. The belt of arable land is wider than on the other streams of the same size. The great timber belt of the Eastern Kentucky carboniferous area is as well stored with valuable materials here as elsewhere in the district. Indeed, the forests of this valley are probably the most absolutely untouched of any of our forest areas. The Cumberland river is here quite navigable in flood seasons; but the high fall at the

passage of the river out of the coal field, in Whitley county, makes the transportation to a market a matter of much difficulty. This will probably be, in a short time, overcome by the establishment of mills on the shore at the falls, where lumber could be shipped by the Cincinnati Southern Railway, or by the construction of a chute to pass the falls. This fertile valley seems to have peculiarly good conditions for the raising of fruit, there being a considerable shipment of dried apples and peaches, which command a ready market. Fruits rarely fail from frost or the ravages of insects, and there is no reason why, by using better varieties than can be raised from seed, there should not be a great extension of this industry. Land is exceedingly low-priced, labor very cheap, and the climate conditions most favorable. When a railway is built through Cumberland Gap there will be no longer any difficulty in the way of transportation, which is now the principal obstacle. As it is, freights from this valley to Baltimore, including hauling to Morristown or other points on the railway, exceed three cents per pound. These mountains produce tolerable grass, and, with a little care in burning the undergrowth, would sustain sheep. As much of the land can be bought for less than a dollar an acre, it ought to attract the attention of persons seeking opportunities for either of these industries. The Upper Cumberland is a stream eminently suited for water-powers, having a great steadiness during almost all seasons, and with reasonable facilities for storage of water. The stream in the dry season of 1874 had a width of about three hundred feet, a depth of two feet, and a current of about two miles an hour. Admirable foundation for dams and other machinery can be had there, and ample space for manufactures secure from flood action.

During the summer of 1874 I made a journey from Grayson Springs through Edmonson, Warren, Todd, Logan, Christian and other neighboring counties, desiring, among other things, to see the economic stones of that region—those used for building as well as those supposed to have a value for lithographic purposes. Without taking up the details of those

examinations, which will be the subject of a special report, I may say that the results of the inquiry were such as to satisfy me that we have in those stones a great and undeveloped source of wealth. The building stones vary much in their character, there being several beds of limestone, differing much in thickness and quality, which commend themselves for this purpose. The best of these is that used by the company quarrying near Bowling Green. This bed lies on the upper part of the great limestone series which immediately underlies the coal measures. It is an oölitic, magnesian limestone, occurring in layers of excellent form for use, readily worked, and with a rare quality of endurance. When first taken from the bed, this stone is rather soft, so that it can be carved with some facility, but when it has been long exposed it acquires a much greater hardness. At least one building in Bowling Green has retained every tool-mark as sharp as when the hammers worked it forty years ago. It is, for a limestone, very resistant to heat, being likely to wear better than any other stone known to me in the Mississippi valley. Add to this a rare beauty of color—a cream tint—and an endurance of this color, we have all the desirable qualities of a building stone well represented. This stone may be sought about one hundred and fifty feet below the top of the main carboniferous limestone throughout the whole section, from the point where it crosses the Ohio to Christian county. I have seen indications of its occurrence all along this line; but at no point have I seen any exposures giving a certainty of its being as perfect in all of its conditions as it is near Bowling Green. But I have no doubt that stones of something like the same good quality will be found over this whole range of hills above referred to. So admirable is the quality of this stone that I look forward with confidence to its furnishing the basis for a large export trade, especially if it can be arranged to transport it by water to the cities of the Ohio and Mississippi rivers.

The lithographic limestones, which are found at a lower point in the carboniferous limestone series, are as yet less

determined in their value than the building stones. The conditions which determine the goodness of this quality of stone are so many, and must be met with such accuracy, that I do not yet feel sure that we have the material to satisfy all these conditions. The extensive series of beds which lead us to hope the possession of a suitable stone for this purpose, were formed under the same general conditions as prevailed in the basin where the most trusted lithographic stone, that of Solenhofen, are found—a sea bottom, whereon an unbroken mass of fine sediment of mingled lime and clay is accumulating, an entire absence of animals large enough for the naked eye to see: these seem to be the conditions under which a lithographic stone must be formed. Unfortunately most of this stone shows from point to point small hard bits, which are probably the remains of some silicious sponge which lived in these waters of the ancient sea. These stones are doubtlessly useful for the making of the coarser sorts of engraving and the ordinary run of crayon work. They may also be fit for ordinary transfer work. I have found as yet none suitable for the very highest grades of work, though I still hope that in the extensive and unexplored district where this stone is found there may be some localities where it occurs in a more perfect state than I have yet seen it. At a number of other points I have seen stones which seem to promise some success in this way; but this same difficulty, arising from the presence of hard points in the mass, seems to threaten their utility. All the lower beds of limestone on the Kentucky river, belonging at the base of the Cincinnati Group, are very promising in appearance. I have also received a stone, presumed to be from the lower part of the Waverly series, on the waters of Triplett Creek, a tributary of Licking river, which, though represented by but a small fragment, seems to possess very promising qualities.

Some of the curiously mottled stones of this section may be used to advantage for interior decoration, for the pavements of halls, and the inlaying of walls. The use of these decorative stones is growing rapidly, and will soon make an impor-

tant demand for these interesting and curiously flecked and mottled limestones.

The forthcoming report on the building stones of Kentucky will consider the questions touched on here in more detail. At present I only desire to call general attention to the importance of the subject.

I have now summarized the work of 1874, and its economic results. It will be seen to have included a wide range of country and of facts. Much of it was experimental and incomplete, though none of it failed to attain an immediate object of some value. The general scientific results will be given in the scientific part of this report.

OPERATIONS DURING THE YEAR 1875.

On their recall from the field, the assistants in charge of the several parties were assembled at the office in Lexington, to work up the results. It required the most vigorous labor, extending through the months from December until May, inclusive, in order to complete the necessary record of the field work. To facilitate this preparation of the results of the Survey for publication, Mr. John R. Procter was employed as assistant and draughtsman at the office, giving his time to the preparation of sections through the various areas where work had been done. Mr. Page spent a part of the winter in finishing the map of the Edmonson county district, and Mr. Mitchell was retained in the field until his work was quite completed. The only work, other than the preparation of the reports, was that done in the chemical laboratory, where the whole work of the year was given to the study of the materials sent in by the several parties during the previous season. A complete account of these researches will be found in the report of Dr. Peter. In the summer of 1875, Mr. Talbutt was ordered to Cumberland Gap to take charge of the collecting of specimens, for chemical analysis, in that section, in connection with work hereafter to be described.

As the Legislature had required an exhibition of the resources of the State at Louisville, six large show-cases,

arranged so as to be capable of being readily transported, were constructed, and the collections arranged so as to be sent to the exhibition at that place. Some part of the time of the officers of the laboratory was given to this work.

Owing to the lateness of the spring, it was found impossible to begin work before the middle of May. The work was arranged as follows: Mr. Norwood and Mr. Beckham, the latter having been absent on leave, to take up some work for the United States Coast Survey between October, 1874, and May, 1875, were sent to complete the work along the lines of railway which traverse the western coal field. Mr. Crandall and Mr. Moore were charged with working up the details of the economic geology of the region to which it was proposed to get access, by means of a railway from Mount Sterling, embracing the counties of Lee and Menifee and a part of the adjacent counties. Mr. Procter was temporarily, at his request, allowed leave of absence to take charge of the camp of the Harvard Summer School of Geology, which, by the invitation of Governor Leslie, came to camp in Kentucky. Mr. W. B. Page was also detached and put in charge of the United States Coast Survey work, to be hereafter described, which was begun in the Cumberland Mountains. Mr. C. Schenk, with Mr. Richardson for aid, began the preparation of a map of the district to be surveyed by Mr. Crandall and Mr. Moore.

After a rapid reconnoissance of Menifee and a part of the neighboring counties, I went in person to Cumberland Gap to lay out a plan of work in that section. To make the reasons for this plan of work more evident, I must give some discussion to the plans which were guiding the Survey at this time. The restrictions which were imposed on the Survey of distributing its work in something like an equal portion in the three districts of the State, though they were not strictly obligatory, were thought to be a proper basis for guidance, as far as it was possible to follow them. The middle section of the State having received less in the previous year, it was determined to devote the largest part of the money expended during

1875 to the middle section of the State and to the eastern field. The work in Menifee county had special reference to the supply of coal and iron to Central Kentucky. On considering the needs of the central belt, it was concluded that it would be, on the whole, best to take up the line of sections from Central Kentucky east to Cumberland Gap, so as to facilitate the work of organizing one or more of the several railways which are looking towards a communication eastward, through that gap, with the Atlantic system of railways. The Cincinnati Southern Railway was geographically nearer the central belt, but it would gain little by an immediate study of its line, its construction being already secured beyond peradventure, while the Survey would find its work much easier if it could be postponed until the road should be passable to trains. There are at least three railways which will need to find a way eastward to the Gap, and they are, one and all, so important to the development of the State that if the Survey can materially aid in securing their construction it will fully justify its existence. These lines are the Kentucky Central, which feels itself compelled to seek eastward extension in compensation for the shorter line of the Cincinnati Southern to Lexington; the Louisville and Nashville, to which the mineral resources of the Gap and a short road to Norfolk, which it secures, must ever be an object; and a third line, which, though only projected, seems to have much to support it and recommend its completion—the Air-line from Chicago to Charleston. Still another line from St. Louis eastward through Southern Kentucky, which is now chartered, and which would afford a more direct route from that great centre to the southern ports than any now existing, also served to increase the needs of a careful study of the Gap region, and made it evident that more could be done to advance the interests of Central Kentucky by work done in that section than by many times the labor expended within what is geographically Central Kentucky. I therefore began my summer work at the Gap, and as rapidly as the gentlemen engaged in the other fields could be spared they were concentrated in the

effort to explore this, the most unknown, as well as the most complicated, part of the geology of Kentucky. In order to aid in the exploration of this region, the camp of the Harvard Summer School of Geology was pitched along with that of my own party, on what is known as the Harlan road, in Bell county, near the Gap.

It is desirable that the citizens of Kentucky should know the circumstances under which this school came to Kentucky, and its relations to the Geological Survey. Having been for ten years an instructor or professor of geology and palæontology in Harvard University, I had endeavored to build up a system of summer instruction in these sciences, one part of which, through the great energy of Professor Agassiz, who cordially adopted the system, had been brought into operation in the school at Penekese. When my selection as State Geologist of Kentucky required my absence from that University for a large part of my time, I still sought to develop this idea of field instruction by starting a summer school of geology. The authorities of the University and my colleagues there having given their assent to the plan, the school was announced as a part of the instruction of the University. Governor Leslie, believing that the best interests of the State would be advanced by having the school begin within this State, extended an invitation to the President of Harvard College to encamp the school here, promising any incidental aid that the Geological Survey might be able to extend in furtherance of its objects. This invitation was accepted, and Mr. John R. Procter, assistant in the Survey, was detached from the Survey and employed by the University to superintend the camp. The number of students was limited to thirty, and this body, with several instructors, was encamped at Camp Harvard during the months of July and August. The Geological Survey was at no expense on account of the school: the sole advantages given by it to the school being the permission extended to the students to accompany the parties in the field, to observe the methods of work, and incidentally to profit by the knowledge of the assistants. In exchange for this the Survey was spared

the expense of maintaining its camp and transportation, and received the valuable assistance of the many able persons who attended the school, several of whom did much useful work for the Survey. The students were limited to the class of teachers, and many of them were men of much experience and high education, so that their observations were really valuable contributions, and greatly aided the operations of the Survey. The teaching consisted in conferences on the field work, with comments from the trained geologists of the party. These were held at 6 o'clock in the morning, so as not to affect the work of the day. Each chief of a field party was called on for his experience in his work, and an effort was made to bring this into harmony with the results obtained by the other parties. The field work was done, in part, by foot-journeys, made within the limits of a day, from the camp, and in part by expeditions with pack-mules, occupying from two to five days. When the summer's work was done, a number of the students accompanied the officers of the Survey upon long expeditions of reconnoissance, which were intended to leave the parties at some point where they could obtain transportation to their homes. One or two instructors employed by the University gave special attention to studies in zoölogy and botany; but the body of the instruction was in geology and palæontology, by the direct method of field work.

The advantages to the Survey and to the State at large, arising from the presence of this school within our borders, have been great. It brought into the Commonwealth more than a score of teachers of science in colleges and academies, giving them a practical lesson in our geology. It has made our State the place whence they will draw their illustrations of the science in their teaching, thus greatly contributing to the wide distribution of a competent knowledge of the geology of the State. Moreover, it brought a considerable amount of money to a section where there is little market for any products.

The region about the Gap was found to be an admirable district for the study of geology. It is, in the first place, a

region of singular beauty and variety of surface. Nowhere in the great Appalachian mountain system have I seen anything to compare with it for varied beauty. On the Kentucky side there is a broad valley in the mountain downfold or synclinal, giving, as in miniature, some of the phenomena of the parks of Colorado. Beyond this valley on the west, at the distance of six miles, rise a sombre, wooded range of excavated mountains, whose tops are three thousand feet above the sea and two thousand feet above the valley, their outlines varied by deep-cut ravines. On the Tennessee side the eye ranges over a vast extent of country ridged by low mountains and intersected by the many tributaries of the Tennessee. In the distance, eighty miles away, rise the long line of peaks of the Unaka range of the Carolinas. The geological section exposes over ten thousand feet of beds, giving a range through nearly the whole of the life-bearing rocks of the most ancient period of our earth's history. Besides this, the geology is of a character to afford the best possible field for the study of those forces which operate to build mountain chains. I have never seen a region having so many admirable localities for the study of dynamical geology.

Despite the exceedingly unhealthy season of 1875—the torrential rains together with great heat to which the students were constantly exposed—no serious illness occurred in the camp, giving the best evidence of the general healthfulness of the region. This alone would suffice to recommend it as a place for summer living, and, combined with the great beauty of the scenery, may properly give it a high place among our places adapted for health resorts.

It is not too much to say, that the school was thoroughly successful, and the State has to congratulate itself on the substantial aid it has given to the development of geological education in this country. The school will continue to be taught in Kentucky as long as it can have the advantage of association with our Survey and a share in its work. As it costs the Survey nothing and avails it much, I sincerely hope for its continuance.

The work done near the Cumberland Gap was so important and multifarious that I am troubled to summarize it. The important scientific results are briefly noticed in the second part of this report. The economic results will be only sketched here. They will be given in more detail in the special reports of the several assistants.

The first object was to get the general outlines of the geological structure of the district. For this purpose several pack-mule journeys were made by different members of the Survey. It was soon evident that the section we had here was quite different from anything which had been seen in the other parts of the State. In place of eight hundred feet of beds above the sub-carboniferous limestones, as in the Greenup section, we had here about three thousand feet of section above the same datum point. The familiar coal and iron beds of the Greenup district are no longer to be recognized, but in their place we have an altogether different set of beds, no one of which can be identified with those in the Ohio district. The search for the coals, though much hindered by the untrodden character of the forests, and the utter want of all previous effort to determine their character and position, was rewarded by the discovery of about twenty different beds of coal in that section, from near the top of the conglomerate to the uppermost beds, over two thousand feet higher in the section. The thickness of these beds has not yet been satisfactorily determined; but so far we have succeeded in determining that at least four of them are of workable thickness and of excellent quality. Some of them promise to yield coal suitable for the manufacture of iron without the intervention of coking, a feature of the utmost importance, as we shall see when we come to consider the value of some iron ores occurring in another part of the section. These coals lie in admirable positions for working. The beds are approximately horizontal, but with dip enough to secure a good drainage in mining workings. They are all, except one, well above the drainage level.

The iron ores of these coal-bearing hills which have yet been discovered are few in number, and scarcely worth consid-

eration. There seems to have been no such drainage of iron-charged waters into the accumulating coal beds and their associated rocks as caused the great richness of ores in the Greenup district. Fortunately this poverty of ores in the coal-bearing rocks is, in a measure, compensated by the greater richness of the ores in the beds which lie nearly a thousand feet below the coal formation. These beds occur in the rocks which immediately overlie the blue limestone of the same age as that of Central Kentucky. They are of the same age as the extensive and rich beds found on the waters of Slate Creek, in Bath county, commonly known as the Preston ore banks, and are to be classed with the far-reaching series known as the Clinton ores, which have been worked successfully in half a hundred furnaces all the way from New York to Georgia. All the exposures of these beds in this district are just at the base of the steep eastward face of the Cumberland Mountains, and, therefore, beyond the limits of Kentucky. Inasmuch, however, as these ores can never be worked to the best advantage except with the coal from the northern side of the mountain, most of which lies within Kentucky, they seemed to call for a study from the Kentucky Geological Survey. More-

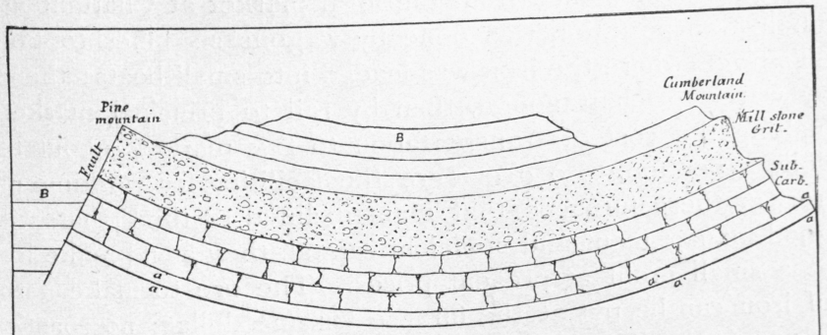


DIAGRAM SHOWING THE CLINTON ORES IN THEIR SUPPOSED EXTENSION BETWEEN THE UPPER VALLEY.

a. a. Clinton Ores in Tennessee.
a'. a'. Supposed extension of Ores beneath the Cumberland Synclinal.
B. B. Coal Measures.

over, these same beds, as will be seen from the accompanying section, extend beneath the carboniferous rocks, and are probably buried at the distance of a thousand feet or so beneath the water line of the upper Cumberland. It will be, possibly, centuries before this source of wealth, so far beneath our feet, will need to be sought by deep mining, but it is wealth in store for the future.

These ores, as exposed in the section immediately east of the Gap, consist of three or more beds of fossiliferous hematite ores, the iron having replaced all the carbonate of lime which originally constituted the bed. These ores are variable in thickness, but may be regarded as averaging each over eighteen inches, and in many places, near the Gap, they are over two feet thick, and hold this depth over extensive areas. The uppermost of these ores is, as yet, the only one that has ever been worked, a considerable amount of ore having been taken from it during this century for the supply of three small furnaces which have existed in this region. Of these, that at the Gap and that at Speedville are still in working order, though not in blast. They are cold-blast charcoal furnaces of small capacity and are now worked at great disadvantage, owing to the distance from the local market at Chattanooga. Their transportation was done by wagons six miles to Powell's river, where the iron was loaded into small boats; thence by water to Chattanooga, then by rail to principal markets, making the cost of transportation to the markets about ten dollars per ton. So great are the facilities for working pig iron in these furnaces, that I am inclined to think that, with good management and sufficient capital, they could make iron at a small profit at present prices. The ore to make a ton of iron can be put at the furnace for one dollar; no roasting is required. The cliff back of the furnaces furnishes fluxing material, of which little is required, and there is an abundance of water-power, if it is desired to use it in place of steam. The question of fuel is the only matter that is not entirely satis factory. The neighboring mountains will furnish all the charcoal timber that can be required for any number of furnaces,

but the transportation is difficult, and the charcoal would be a considerable element of cost. It would not, however, be as costly as in the Hanging Rock iron district. As soon as a railway is pushed through the Cumberland Gap, which cannot be long delayed, the transportation of charcoal will be much facilitated, and furnaces can be profitably built along its line, using the iron from this district and the charcoal or stone-coal from the vast forests and stone-coal beds of Kentucky. When this is brought about, these ores will follow the economic law of such products and be carried to the fuel, rather than the fuel to the ores. The points where the railway will necessarily cross Yellow Creek and Cumberland river will then be the advantageous sites for furnaces. Two short spur roads built along the base of the Cumberland Mountain, at a cost of, say ten thousand dollars per mile, and extending five miles each way, would give access to a sufficient supply for fifty thirty-ton furnaces for a century to come. Most of these would naturally find their places on the Kentucky side of the mountain.

I am of the fixed opinion, that in this region, as at the Green River district, we have altogether peculiar advantages for the production of pig iron of high grade with extreme economy. These conditions are, iron at less cost than at any other point, charcoal fuel from cheap lands, or stone-coal fuel at a low cost, with good water-power, fluxes, and stone for hearths, all within easy access. Along with this, we have the proximity of two admirable agricultural regions, both contributing to keep down the cost of production. With a railway completed, the following are the probable costs of the production of cold-blast iron:

Ore, two tons, at $1 per ton	$2 00
Charcoal, 200 bushels, at 3 cents	6 00
Flux	25
Labor	2 50
Wear of plant and interest	1 00
Incidentals	1 00
Total	$12 75

For stone-coal iron about as follows:

Ore, two tons, at $1 per ton	$2 00
Two tons of coal, at $1 50 per ton	3 00
Labor, &c.	4 75
Total	$9 75

The above prices, should they be increased by twenty-five per cent., will still fall below the cost of making iron of this grade in any other American iron district, except, perhaps, in Western Kentucky, where for charcoal furnaces the rates will be about the same.

In Eastern Pennsylvania, the only region that can begin to compete with these advantages, the cost of making the cheapest iron is, at the present time, not less than $20 per ton.

This shows that the difference is very much in favor of the conditions now existing in the Cumberland Gap district. The small area of the anthracite fields and the great demand for their products insures a high price for that coal. Charcoal furnaces on a large scale in the Pennsylvania district are hardly possible, so their magnificent ores are sure to be heavily taxed for fuel. Moreover, they are all in the hands of companies who hold them at high prices. This Cumberland area of coal and iron is so great that it will be long before it can be monopolized so as to greatly heighten the cost of production. There can be no doubt of the existence of these ores along the whole of the Cumberland Mountain range, from near Pound Gap to Jacksboro, in Tennessee, and at various points further to the south it appears in great thickness.

The importance of these iron deposits is so great that every effort should be made to get some system of transportation which will make their development possible. This can be best accomplished by a railway extending from the systems of railroads in Central Kentucky to the roads of East Tennessee. Such a road would at once open the markets of the Ohio valley and of the seaboard. The distance of the cities of Cin-

cinnati and Louisville will be not far from two hundred miles, so that the transportation to those points would cost about two dollars and a half per ton. The distance from the ports of Norfolk and Baltimore would be about four hundred miles, bringing the transportation to those markets up to about five dollars per ton. This would make the cost of raw coal pig about thirteen dollars in Cincinnati and fifteen dollars in the seaports. Adding one third for profit and commissions, we have the figures fifteen and seventeen and one half as the selling price in these markets. At these prices the irons would be worked at a profit even at the present low state of the market.

At the present time the producing capacity of the iron furnaces of the United States is about double the total consumption of the country. The result is, the greater part of the furnaces are subjected to a destructive competition which keeps them in idleness or in operation at a loss. There is no room for additions to the means of producing iron, unless in localities which can make the metal at rates much below the average cost. A very large number of furnaces, where the ore and coal are dug at large cost, and are transported to great distances, must remain unprofitable; but the national demand is so great that ore regions that can furnish high grades of ores at low prices, cheap fuel, and ready transportation, must become the seats of permanent industries. I am furthermore of the opinion, that, with such opportunities as are offered at several points in the Ohio valley for the production of cheap iron, we can, within ten years, ship pig metal to England and to continental Europe. The high price of coal in all that region and its growing scarcity, the depth to which the workings for ore have been carried, the progressively leaner and leaner kinds to which the furnaces are driven for supply, all are fast leading to the time when our furnaces will begin to compete successfully with their own. I am fully satisfied, that, with a railway from Central Kentucky to the East Tennessee road, via Cumberland Gap, we could, if the business were conducted with sufficient care, produce pig metal at a cost

which would enable us, at present prices, to ship it to Europe at a profit. These advantages are daily counting more and more in our favor, through the constant rise in the price of the elements of iron-making in Europe, and the equally constant gain in capital and cheapening of labor with us.

I should also notice the advantages of this section for manufacturing industries which will arise when a railway is brought through the Gap. The large amount of hard and soft wood, the abundance of good water-powers, the nearness to extensive agricultural regions on the north and south, all point to its fitness for this work.

To my considerable surprise, I found that the agricultural value of the uplands and mountain tops of the several mountains about Cumberland Gap had been greatly underrated. Wherever the rock is not too near the surface, we have an excellent arable land, which seems to bring good crops with great steadiness for many years, deserving to rank among the first of the second-class soils of the State.

As near as could be determined without detailed study, about two fifths of the surface of Bell county is good arable soil, the remainder being too rocky for plow culture; of this area about one fifth would make fair pasture land of the second-class if cleared. Its proper use, however, is for growing timber, for which it is peculiarly well fitted. The special reports of the assistants will give the details as to the constitution of the forests.

On the first of September camp at Camp Harvard was broken, and the several assistants left to make special explorations in regions too distant to be reached from the camp. Assistant Crandall made a reconnoissance down the Cumberland, by way of Barbourville and Williamsburg, to the Falls of the Cumberland; thence northward to Danville, whence he went to resume his work in the Menifee county district.

Mr. P. N. Moore was instructed to make a journey along the Cumberland Mountain to Stony Gap; thence across to Abingdon, Virginia, in order to see the character of the country as affecting the question of railway connections from

Kentucky in that direction; thence back to Pound Gap with the same view, and from Pound Gap down the Kentucky river to Lexington. This journey was sucessfully accomplished, and added much to our knowledge of the border line of the State and the chances of railways seeking eastward connections. The report of this reconnoissance is to be published in the fourth volume of these reports.

Mr. Norwood was put in charge of the section from the Gap to Livingston, which was intended to form the basis for the report on that line of passage for a trunk railway from the railways of Central Kentucky to the East Tennessee section. This report has been completed and published in the second volume.

Mr. J. H. Talbutt, second assistant in chemistry, was sent with Mr. Crandall to make collections of soils on the route pursued by him. In the course of this journey he visited Rockcastle Springs to make collections of the waters of these interesting sources as a basis for some special analyses.

Work on this section was closed at the end of August. On the first of September Camp Harvard was struck, and I left the Gap in company with Carr and Procter, the latter having returned to the Survey after the expiration of his engagement with Harvard College as the chief of its camp. In order to examine a number of questions, our route was laid in a general easterly direction, along the line between Kentucky and Tennessee, and to the northward thereof. My principal object was to determine the character of the country with reference to the building of an east and west railway, which, in the immediate future, will be demanded to give a direct way from St. Louis to Charleston and Norfolk. At the same time, I wished to see the general geology of the region with reference to detailed work in coming years should the Survey be continued. In order to see the character of the Cumberland Mountain beyond the region traversed during our summer's work, our reconnoissance was arranged so as to take us as far as Jacksboro, Tenn.; thence through Big Creek Gap back again into Kentucky. By this route we were enabled to

see the next pass south of Cumberland Gap, by which a way out from Kentucky to East Tennessee can be made. From Cumberland Gap the Clinton iron ores continue, without interruption, to Jacksboro; at least, they are found from point to point along the line; but about ten miles south of the Gap they cease to form foot hills, as in the section north of that point, and are merged in the face of the mountain. This is probably due to an actual loss in the resisting power of the ores to the action of weathering and to a stronger resisting power of the rocks which cap the mountain, viz: the lower beds of the Millstone grit. This peculiarity will cause the beds in this part of the section to be much less valuable than on the section nearer the Gap, on account of the difficulties of working being much greater. While the beds near the Gap can be reached for a long time by stripping the overlying matter from them, those further south have so much above them that they must shortly be worked by underground mining. At Jacksboro the Cumberland Mountain abuts against the great Tennessee table land and is lost, a valley separating it from that vast undisturbed mass. The Big Creek, which flows through a curious rift in the mountain, is the first stream I have seen crossing the ridge of the Cumberland. It passes over the edges of vertically upturned beds, extending from the Millstone grit down to the Knox beds or the equivalent of the California sandstone. The passage through the Cumberland range itself is one of the most perfect imaginable, it being possible to pass it with grades of forty feet to the mile, with no very deep cuts and no long tunnel; but just beyond the Gap the table land rises quite rapidly, so as to make a serious barrier to the passage of a railway. Beyond this the curious erosion ridge of the Jellico Mountains makes still other difficulties, so that it cannot be regarded as furnishing the same easy access to the Tennessee valley that is afforded by the Cumberland Gap route, where the only serious barrier is the tunnel of four thousand feet at the Gap itself.

Beyond Big Creek Gap the traveled road climbs rapidly until we attain a height of more than a thousand feet above

the stream, and then descends to the waters of the Cumberland river. After passing Pine Mountain and Jellico Mountain, which extends in a northeast and southwest direction, we come upon an extensive region of rather low-lying table land, upon the waters of the several branches of the Cumberland, falling into the main stream, from the south. Some of these tributaries have a curious sluggishness. The most conspicuous instance of this is Marshy Creek, which has not only ceased to cut its bed, but is clearly silting up at the present time. I cannot account for its singular character without supposing a depression of this district since the time when it worked out its bed. This is a matter that will be considered in the succeeding part of this report. This depressed character of the valleys, which gives them borders often as swampy as those of the streams in the Jackson Purchase, is a serious hindrance to their fertility. Where the road from Jellico Cross-roads to Monticello crosses Marshy Creek the shores, for many rods in width, are too wet for cultivation. I am inclined to think that something could be done by ditching to benefit these lands, and more by aiding the stream by clearing away the obstructions to its free course. The next considerable stream is the charming river known as the Big South Fork. I do not know a more attractive stream than this strong-flowing river, deep set in the cliffs of the lower coal measures. It does not creep in muddy banks like most of the streams on the east, but breaks rapidly from the Tennessee table land through the country to the main stream. From its admirable volume and the constant character given it by the rather porous rocks which underlie the country on either side of the river, it is well adapted for water-powers, and would make a capital stream for continuing, by locks and dams, the water navigation of the Cumberland far into the table land district. The Cincinnati Southern Railway, while it has made the improvement of the navigation of the stream unnecessary at present, has made it possible to look forward to the time when its water-powers may become

of much value, placed as they are on the line of a great north and south highway.

The country on either side of the road from the crossing of Jellico Mountain has a very considerable agricultural value. The timber to the west of the Cumberland Mountain is admirable in its quality and size—a good deal of the precious woods, as we may call the walnut and hickory, and a vast quantity of white oak of admirable quality. Tulip trees abound, and are often of noble proportions. As a whole, the forests are better than anything I have seen out of Western Kentucky. Between Marshy Creek and the Big South Fork the timbering changes. The country is no longer cut into the rugged ridges, with stony hill lines, but becomes a table land, tolerably flat, and with streams about three hundred feet below the general level. On these levels the timber is principally yellow pine, of good shape—trees generally from ten to twenty inches in diameter, tall and straight, often running up to ninety feet in height. The general character of soil in these pine forests is very light and thin. With care in manuring they would serve a fair purpose, but for the ordinary rough usage of our country they are unpromising. As a whole, the section traversed by me lying to the east of the Cincinnati road is good for agricultural purposes, and exceedingly valuable for its timber. As regards coals, I am inclined to think, that just west of Pine Mountain we have the whole of the lower coal section beneath our feet, which, on the other side of the mountain, rises more than a thousand feet above this level. In other words, that the section, which at Cumberland Gap contains about twenty coal levels in about two hundred feet of strata, is all or nearly all below the level of the earth on the west side of Pine Mountain. From this point west, the beds appear gradually to rise until we seem to have come down near to the conglomerate, when we pass Marshy Creek. The pine forest above described probably rests on the conglomerate series. At the Cincinnati Southern Railway we have a considerable thickness of section, say one hundred feet, composed of very soft reddish sandstones, with

intercalated clays, the whole being much less coherent than anything I have ever seen in our Kentucky coal measures at any other point. The beds seem to have been exceedingly affected by water currents at the time of their formation. I could discover no pebbles in the section, nor any traces of coals; but a mile or two to the west the rock begins to contain pebbles in considerable quantities. In less than one hundred feet of descent we come upon most unmistakable conglomerate. The total thickness of the section, from the Cincinnati Southern Railway at Pine Knot to the level of the Big South Fork, is about seven hundred feet, which may be taken as the thickness of the section between the railway and the top of the main limestone. Two coals appear in large stains, one at four hundred and fifty feet below the railway, the other at four hundred and ninety feet below that level. There may be others, but only these were clearly shown. The upper hard sandstone of this series appears in cliffs of about sixty feet high, and gives the same topography to this section that is given by the fifth sandstone (so called in Dr. Owen's report) of Edmonson and Grayson counties. This sandstone is capped by the level surface of the country. The retreating cliffs are often brought so close together that there is barely place for a road between their walls on either side.

What is apparently the upper of the two coals seen at the Big South Fork appears again as a stain on Little South Fork, where it is one hundred feet below the top of the hill, and probably two hundred or more feet above where it occurs on Big South Fork. As this section is almost uninhabited, no effort has been made to open these coals, so their character is quite unknown. The evidences of a continued southeast dip are maintained throughout this section. The rocks rise to the northwest at the rate of about twenty-five feet to a mile; so that, on the waters of Little South Fork, we pass deep down into the Chester series of rocks, if not into the St. Louis limestone. The coal measures cling along the hills, which are five or six hundred feet above the valleys, so that there is still a good area of coal over the face of the coun-

try. As soon as we descend into the limestone the country becomes exceedingly fertile, and from ten miles or more south of Monticello, the waterless valley, where the stream flows in the caverned rock, bears the best crops of corn I have ever seen. The fertility extends only as high as the middle measures of the Chester, where the rock comes to the surface, and the growth of cedars begins. The quantity of this cedar growth is quite surprising. There are thousands of acres of it, in the aggregate, giving trees of very large size for this kind of wood. Near to transportation, these trees would have a considerable money value. The valley broadens as we go north until it is more than a mile wide, and receives other valleys equally fertile but waterless. About Monticello the coals of the lower conglomerate still hold their place, but are little worked. The details of their character are well given in the report of Mr. Joseph Leslie.*

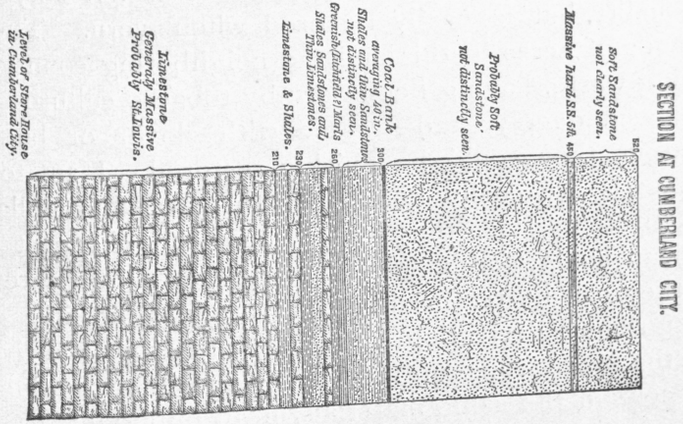
Where the streams emerge from the limestone they have the admirable qualities which belong to streams gathered in caverns: they are clear, cool, and of very uniform volume. When we add to these features the possession of high rocky banks, with admirable sites for dams and mills, we represent their admirable mill value. About two miles beyond Monticello, Beaver Creek furnished an admirable succession of water-powers; at Rankin's Mill the volume is about seven million gallons per diem, falling twenty feet. The dam could be raised to forty feet, with excellent walls, or several of thirty feet could be made within five miles.

An old ruined blast furnace makes a very picturesque object on the bank of the stream. It was hard to find anything about its origin. From all I could gather, I conclude that it was built in or about 1815, and was unfortunately chilled in the first blast, and never used again, though it seems to have been cut out. The ore sought to be used is the limestone top ore, which has given the admirable iron of the Red River furnaces. The openings where the few tons of ore which lie in the little stock yard were taken are no longer known; but

*See the fourth volume of Dr. Owen's Survey.

this ore can be found at any point in this district, and in sufficient quantities to repay working, if exit could be had for furnace products. The specimens I have seen were of high grade, and probably running over forty-five per cent. of iron. Analyses will be found in the forthcoming report of Dr. Peter and Mr. Talbutt.

From Monticello west the beds do not seem to ascend with anything like the rapidity with which they rise in the region to the eastward. This is a surprising but advantageous feature, inasmuch as it prolongs the extension of the coals to the westward for a number of miles. Moreover, we have here some very high ridges in Poplar and Short Mountains. These hills are not really uplifts, though they have this appearance. They are, in fact, the remains of a great extension of coal which has been worn down to a lot of shreds and patches. The westernmost of these is a noble outlier of the coal field, standing like an island in the midst of the limestone rocks. At present this is extensively mined at Cumberland City, the coal being carried to the river on a railway, and thence to Nashville by boat. The coal is of excellent quality and of fair thickness. The accompanying section gives its general character and relation to the neighboring beds:



This small field can supply no long-continued demand, even at the present moderate rate of mining; but the same coal occurs in abundance in the hills around Monticello, so that any railway looking to this source of supply would soon be able to strike the unbroken field on the east. These coals are the same as those worked near Livingston, and have, doubtless, the same good qualities. It will, like that at Livingston, be found moderately well fitted for gas purposes, and may work well in the iron furnace without coking. For analyses of this coal see the last report of Dr. Peter and Mr. Talbutt.

On the face of the hill, at the point indicated on the diagram, marly beds, identical with the formation termed by the Survey the Leitchfield marls, appear. All the way for the last twenty-five miles there have been traces of these marls, but they are shown here with great distinctness. These marls are of no little scientific interest, and are also very important in an economic point of view. They contain a notable amount of soda and potash: some free and ready for appropriation by plants, and some held in the form of insoluble silicates. This will be a great store for the agriculture of this country when it becomes sufficiently advanced to profit by all its opportunities.

The land which lies on the limestone is not only of very high quality but is easily restored when worn. There are thousands of acres in this and the neighboring county, which are lying waste, having been worn by tobacco culture: if they are plowed deeply, and treated with clover or buckwheat plowed in, they could be quickly restored. I am told that these lands are easily bought for three or four dollars per acre. In that case, they are among the cheapest of our American lands; for, at the expense of a little careful culture, they can be restored to their original fertility. Unlike soils of remote derivation, such as glacial soils and river bottoms, the worn soils of Kentucky have beneath them beds which contain the same materials, in all important respects, as the beds above, which once were fertile. All that is necessary

is to bring up some of this underlying matter, mingle it with vegetable materials, and allow a free movement of air and water through its mass, in order to bring it again to more than its pristine fertility. On this point I can speak, not only from theory, but from experience; and I regard it as a very important feature in our soils that this ready refertilization can be accomplished.

At this point I must refer to the coal oil products, which are accessible from the surface in this region. It has long been known that coal oil was to be had in this district. More than forty years ago a missionary preacher of this region found, in his wanderings, a spring near Burksville: the precise point I have not been able to determine. This oil he bottled and sold in large quantities in Western Kentucky for its healing properties. During the coal oil excitement of a few years ago a good deal of boring was done in this section; and in one of the reports of the Survey, for which materials are now being gathered, we have endeavored to trace the results in detail. It is no great misfortune that free flowing wells of light coal oils have not been discovered here. The sources of production of this material are so numerous, that, even with ample means of transportation, it would not be profitable to ship it to a market at present prices or at any prices that are likely to prevail for many years to come. This section is far more fortunate in the possession of an ample supply of the heavy or lubricating oils, which are easily obtained by wells sunk deep enough to penetrate the beds of the black shale, which lie about two hundred feet below the base of the sub-carboniferous limestone. This black shale, which has here a thickness not far from fifty feet, seems to be the source of production and reservoir of this oil. It is not easy to account for the great quantity of the oil found at this point, and the comparative paucity at other points. It is a well known fact, however, that, wherever this black shale is found south of the Ohio, it is richly stored with this heavy or lubricating oil. Before the discovery of the flowing wells of Pennsylvania, these shales were extensively and profitably worked

near Vanceburg, Kentucky, for the oil, which was obtained by distilling the shale. It is stated that the yield was as much as fifteen per cent. of the mass. It seems likely, from all I have seen, that wherever the beds occur above the drainage of the country, the coal oil has been leached out, except that which is clearly combined with the rock in an insoluble condition. This insoluble oil can only be extracted by distillation. When, however, this oil has been kept in the rock by the action of any local causes, it may remain so full of oil that it will flow into any well that is carried down into the shale beds.

The long low ridge known to geologists as the Cincinnati axis, which extends from north of that city to south of Nashville, serves, it may be, to confine the rocks on the east, so that their contents are not free to escape. Besides this, the whole, or nearly the whole, of the black shale west of the Cumberland is actually below the drainage, so that it has never been freely traversed by subterranean water.

Wherever this shale has been penetrated by boring, in the district east of the Cumberland, more or less of this oil has flowed into the opening. One well is now in operation on the head waters of Otter Creek, belonging to R. L. Carter, Esq., of Cumberland City. I am informed by him that as much as fifty barrels per diem have been pumped from this well, and that it shows no sign of diminishing in quantity. The only difficulty in the way of obtaining the oil arises from the choking of the well by paraffine. There is, however, a very considerable obstruction to the extensive working of these wells in the difficulty of transportation. The oil has to be hauled in wagons about twelve miles to Cumberland City, sent thence to the river by rail, and from the terminus of the rail again transhipped to boats and taken to Nashville. The roads are very bad, the river untrustworthy, only affording transportation for a part of the year, so the cost of taking the oil to Nashville is rather over two dollars per barrel. The building of a railway across this field would reduce the transportation to Louisville to less than one third of what it is at present,

and practically add five cents per gallon to the value of the raw product. The importance of this source of wealth to the interests of the State is hard to overestimate. The consumption of these lubricating oils is growing, from year to year, with great rapidity. The sources of supply are much more limited than for the other oils. The oil from the Cumberland district is, I am informed, much more esteemed than the other oils in the market for use in high latitudes, where the intensity of the winter cold makes it necessary to exercise great care to prevent the lubricating materials from congealing.

Although there may be local differences in the composition of this rock, which will give some wells the advantage of others, there seems to be no good reason to doubt that a very large area is underlaid by the beds that bear the oil, and that we may fairly reckon that there is a region of a thousand or more square miles in Clinton and Wayne and the adjoining counties which bear the oil. I am inclined to believe that, from this point all the way to Pine Mountain, the same conditions which have caused the great richness of these beds continue, and that it is merely a question of depth of boring whether the oil is found or not; but at the western face of Pine Mountain it would be necessary to penetrate about twenty-five hundred feet of beds before coming to the oil-bearing rock, while in these counties the greatest depth below the drainage will not much exceed seven hundred feet. I have assured information of the discovery of oil of this grade at Carter's well, on Otter Creek, and at the Phillips well, on Oil Fork of Bear Creek. I have unconfirmed, though seemingly trustworthy statements, of the existence of similar oil at several other points in this section, which would give a total area of at least one thousand square miles, which had been in a fashion explored by borings, and found to contain this oil. As the exploration was practically limited to the area where lubricating oil was obtained in most of the wells that went deep enough to tap the black shale, there seems no reason to limit its extension to this rather narrow

field. I am inclined to recommend a search for it at all points where the black shale is below the drainage. Measuring downwards from the base of the sub-carboniferous limestone, it will be safe to allow a distance of from five hundred feet in Northeastern Kentucky to two hundred feet in this section, before expecting to reach the black shale. It may always be known by its black color, and by the strong smell of coal oil it gives out. The boring should be carried quite through the shale, which ranges from about one hundred and fifty feet thick in the Ohio River section to about fifty feet, or even less, near the Tennessee line.

It may not be out of place to call attention to the prospective value of this black shale as a source of future power to the Commonwealth. Its area in Kentucky is probably not less than eighteen thousand square miles, and its thickness may safely be averaged at one hundred feet. Assuming that it contains, in the shape of free and combined oil, the equivalent of fifteen per cent. of its mass, we see that it is equal to eighteen thousand square miles of oil fifteen feet thick. Assuming that, volume for volume, it is worth the same for fuel as good coal, the total value of this deposit probably much exceeds that of a coal bed of the same thickness. Measured by the present price of the oil and paraffine it produces, this mass of shale might have been regarded in 1855 as overvaluing, by many times, the whole coal deposits of the State. At this rate of yield, there would be four million gallons to each acre of surface, and two thousand four hundred million to the square mile, so that the gross product to the square mile would, at the present price of these oils, have been something like a thousand million of dollars. The finding of flowing wells of light and of lubricating oils seemed to make this source of wealth that had dawned on the State sink into utter worthlessness. I doubt, however, whether we may not fairly look forward to this wonderful deposit of organic matter as a future source of varied and important chemical products, and of immense wealth to the regions underlaid by it. There seems no room to doubt that the available areas of coal oil

are being rapidly drained of their store, while the consumption grows apace. The natural resort will then be to these shales, which, even allowing that only one tenth of the estimated quantity is available, will still be of far greater value than all the other known resources of the State.

I now pass to another branch of the economic work of the Survey, which touches closely on the scientific matters which are to be taken up in the next section. I refer to the geodetic or triangulation work of the State which is now in course of being executed under the direction and at the expense of the United States Coast Survey. In the preliminary report made to the Legislature in December, 1873, I indicated the importance of securing the co-operation of the United States Government in this work of making a trigonometrical survey of the State as a basis for a good map of our territory. This action was, with some difficulty, secured through the energetic aid of Senator Stevenson and the Governor of Kentucky. I should say that the State of Kentucky had done much to bring this system of Government aid to State surveys into operation by a strong reference thereto in the annual message of Governor Stevenson, and by a resolution of her Legislature looking to the same object. This action greatly strengthened the hands of Professor Peirce, the late Superintendent of the Coast Survey, who was then seeking the consent of Congress to this wise extension of the work of the Coast Survey over the interior States. This plan, which is destined in time to give us a general basis for all the map work of the country, was extended to Kentucky in 1875. Assistant W. B. Page was transferred to the Coast Survey, and in its service is employed, for five months each year, in carrying a system of triangulation over the State, beginning in the Cumberland Mountains near Cumberland Gap, and extending westward as far as the Mississippi, in time.

During the season of 1875 the work was carried as far west as the Rockcastle river, or rather the preliminary reconnoissance was carried to that point. This Survey will give us a system of lines and stations over the whole State, every one of which

will be determined as to position with such accuracy that we can safely say that it is not more than three feet in error, or, in other words, is more accurately determined than we can represent it on any map. When we consider that, at the present time, there are not more than one tenth the county seats in Kentucky, the true position of which have been determined within a probable error of two to five miles, we can see the advantage this will give as a basis for the map of the State. So important is this form of work that no country now ventures on the construction of a map without first laying the foundation for it in this form of work. In no other way is it possible to arrive at anything like accuracy of result in map making. I count it a great good fortune for the State to have secured this important aid in the study of her territory. To have initiated such a work would have required a very large expenditure of money, more, indeed, than I should have been willing to have expended from the means which has been or is likely to be appropriated by the State for the Geological Survey.

In order to secure the continuance of this goverment work within our borders, it is necessary, by the terms of the law, that the Geological Survey be maintained. With a view to obtaining all the immediate results that could be had from this triangulation, I have, with the consent of Capt. Patterson, Superintendent of the Coast Survey, joined two of the officers of the Geological Survey to his party of triangulators: Mr. Anthon Lee Jonas, Aid Kentucky Survey, is charged with making a rapid reconnoissance of all the roads and streams traversed by the geodetic party. This will enable us to give a great deal of correction to the general map of the State, and to amass a great quantity of information concerning the possible ways for roads, rail and common, the available sites for mill-powers, &c. Mr. C. W. Beckham, Assistant Kentucky Survey, is charged with the study of the timber and soils, for which work he has had special training during the past two years. These gentlemen are also charged with the work of determining approximately the character of all sec-

tions where the rocks are exposed, so that the work of the geologist may be much reduced when the final geological work is begun.

With the close of the month of October all the parties of the Survey were withdrawn from the field. This was done because of the approaching exhaustion of the appropriations made by the last Legislature to be expended in 1874 and 1875. These appropriations had been drawn upon with care, but were now reduced to the point where only enough was left for the preparation of the work for publication, and the making of the necessary lithographic and stereotype plates. Since the close of the work about Cumberland Gap, in September, 1875, Mr. Crandall has completed his work in the Menifee district, and made a careful study of the region about Warfield, on Tug Fork of the Chatterawha or Big Sandy; Mr. Moore has completed his work in the Red River iron district; Mr. Norwood returned to the western part of the State, where he was busied in the survey of the Breckinridge coal district, near Cloverport, and in the completion of some other work on the coal fields of Western Kentucky; at the chemical laboratory Dr. Peter and Mr. Talbutt have been busied with the analyses connected with the field work; Mr. Schenk closed his work in the Menifee district, and has been occupied with the office work of his map; Mr. John R. Procter, after spending the month of September with me in a reconnoissance from Cumberland Gap to Glasgow, returned to Lexington to take up the work of preparing the diagrams and maps of the Survey for publication; Mr. Lucien Carr, volunteer assistant in charge of the researches into antiquities of our State, has been occupied in the arrangement of the large collections which have been gathered, and in the preparation of lists of the various evidences of extinct races which have inhabited our territory. The Director of the Survey has been engaged, during the time he has been in the service of the State, in the preparation of reports, and in the general supervision of the Survey. The extreme economy which I felt it necessary to exercise in the expenditure of

the money intrusted to me has made the work of administration difficult and harassing to a high degree. The correspondence of the Survey has grown to very large proportions. It requires at least two thousand letters per annum to do what is imperatively required to keep the inquiries by letter properly answered. Since its organization the Survey has paid nothing for office rent, its work rooms having been generously loaned by the Kentucky University. Nothing has been paid for clerical work. Apart from small aid from the other officers of the Survey, I have done it myself, or it has been done by members of my family. By such means it has been possible to reduce the expenses of administration, I believe, to a less sum than they have ever represented in a considerable survey. In 1874 and 1875 the Survey has had an average of ten salaried officers in its service. (See Appendix.)

Last, but by no means least, in the history of the work of the Survey, I wish to recount the beginnings, in the teaching of natural science, which have been made by its officers, at the State Agricultural School. Through the coöperation of Regent Bowman and President Patterson, it has been possible to arrange it so that Mr. Crandall is paid by the Agricultural School during a part of his winter absence from the field, to give some instruction in economic science, as illustrated by the geology of Kentucky. Mr. Page is also employed to give some teaching in engineering, with special reference to the various work which is necessary in the present state of Kentucky. If the Legislature continues the work I shall endeavor to promote the extension of this relation between the officers of the Survey and the State Agricultural College, so that the youth of our State may learn from the men who have been taught by the facts themselves the true sources of wealth in the State. To do this effectually there should be built at the State Agricultural School a sufficient building to furnish laboratory room and a place to exhibit the rapidly growing collection, which will soon come to represent admirably the natural wealth of the State, and give a basis for its further exploration. In connection with their collections, the assistants of the Survey might well be required to give, say, each one month's time to lecturing on the several branches of the science in which they are experts. In this fashion it would then be easy, while it is now impossible, for the student to acquire information as to the resources of his native State.

PLAN FOR THE CONTINUATION OF THE SURVEY.

In the foregoing pages I have endeavored to give what was necessary to enable the reader to supplement the record of the operations of the Survey afforded by the previous volumes of reports. I now propose to submit the general plan for the operations of the Survey as far as they can be determined by the experience of the two years of work already done. For the sake of clearness, I shall speak firstly of the topographical work, secondly of the geological work, thirdly of the chemical work, and lastly of the several incidental undertakings, which, though important, cannot be classed with the foregoing divisions.

I take the topographical work first for the good reason that it is the necessary foundation of all the other work; the most difficult and the most costly as well. The goodness and final utility of a survey depends more upon the character of the topographical work than upon any other matter connected only with its operations.

A general statement only of the resources of any country can be given without a good map; for, with a good map, accuracy begins.

Years before the Geological Survey was revived, I endeavored to secure the basis for topographical work in Kentucky and our other States by urging the plan, already referred to, of having the Federal Government cover the State with a system of carefully measured lines. When the Federal Government gave its consent to this project it was conditioned on the existence of a geological and topographical survey in the States where it should be begun. As soon as the Geological Survey of Kentucky came under my control, the Governor of

the State made formal application to be allowed the advantages of the system; but the small amount of money given to the Coast Survey for this purpose had already been appropriated, and it was necessary to await the action of the next Congress. The result was, that the work was not commenced in Kentucky until the season of 1875. Unfortunately, the exigencies of the work of the Geological Survey demanded that topographical maps should be begun immediately on the organization of the Survey.

About two thousand square miles, or somewhere near one eighteenth of the State, and about one ninth of the mineral districts, have been well mapped; but, while every effort has been made to put this work into the shape necessary to have it fit into the triangulation scheme when it comes to completion, I have constantly been conscious that the work has been done at a great disadvantage, and that it was a very great misfortune that the map-making could not be suspended until the triangulation had been fairly begun, then introduced in the region where that work was finished, and never carried into a field until the triangulation had preceded it. This triangulation work was commenced near Cumberland Gap, and can be extended so as to cover about three thousand square miles a year. The work first done will consist of a strip, say about thirty miles wide, extended directly across the State on the most practicable line; from this base the work will be continued until it covers the whole State with its lines. Following this work, the topographers can fit their maps on to the determined lines with rapidity and certainty. The maps thus made would serve for all the needs of the country that can at present be foreseen. As this succession of work is that which is required in all thoroughly sound topography, I shall, in case the Survey is continued, and I am not otherwise instructed by the law, accept it as the basis on which to conduct the work while it remains in my hands.

The geological work requires the topography for its foundation, if it is to be done in detail and with the best economic result. While he is without an accurate map, the

geologist can only give verbal pictures of the distribution of rocks, aided by diagrams to show how they lie with reference to each other; but with a detailed map—one that gives each house and field and road—he can show just where the underground beds are to be found. Therefore, all detailed geological studies should be done with the accurate map, which it is our aim to make, already in hand. Therefore, it would be best for the final geological study to have it follow the topographical work. There is still a good deal of work in Kentucky that the geologist can do, and by doing, greatly advance the interests of the State; but the results of the accurate measurements and close study of facts, that form the most valuable part of economic geology, cannot be laid down without first having a map in hand—a map that gives the area of every hill, the place of every road, house, and field, which can then be colored to show the limits of every distinct bed, and illustrated by diagrams showing the underground lay of the beds, and accompanied by detailed descriptions. This is the end to be sought, and to be effectually attained, the several steps must be taken in their order: First, the triangulation; then the actual map-making, having that triangulation for a basis; then the detailed geological work.

It will be noticed that in the preliminary report made in 1873, and republished herewith, there is a sketch of a plan for the conduct of the Survey as proposed. It will be seen that the work there laid out was limited to the study of the several resources near to the great lines of communication, and a general study only of the other regions not found by existing ways. This work has been approximately done in the fashion proposed. All the completed roads which traverse mineral districts have been studied, and it only remains to complete the study of the rivers as far as they may furnish a basis for the development of the mineral and other resources of the State. Considerable progress has been made in the work, and in another year it could be substantially completed. But every step of this labor has shown me that the existing transportation routes of Kentucky are utterly inadequate to the task of giving access

to the wealth of the State, and that the Geological Survey should be used as a means of setting forth the resources of the regions yet unpenetrated by railways, so that capitalists may be induced to make them accessible at the earliest possible time.

On the eastern side of Kentucky there is a barrier cutting her off from the sea and barring her people and the States to the westward from direct access to the wealth that comes from direct trade with the world beyond. This barrier consists of a region about one hundred miles across, into which no railway has penetrated, though the railways on either side come up to its boundaries at several points.

Looking at an ordinary map, we would suppose that this region was a desert and impracticable region, promising nothing and defying the efforts of engineering science, so difficult is it to account for the commercial fatuity that leaves it untraversed by great highways. But when we penetrate it, we find there a wilderness, it is true, in parts almost untrodden, but, withal, a fairly fertile soil and a forest timbering unsurpassed in America for its variety and its size. In place of impassable mountains, we find a region through which a railway can be carried with less cost than over an equal surface of our blue grass land; and, more important than all the rest, the whole of this region contains the richest combination of coal, iron, salt, and oil that has been found anywhere in the world.

Immigration, if immigration can be had in the right shape, and does not come as mere importation of men, is undoubtedly a great need of Kentucky; but this, to be had properly, should come naturally, and the only way to secure this is to put the State on great east and west lines of transportation, so that it will no longer be difficult for the immigrant to find his way to her borders. The small amount of foreign immigration Kentucky has received is principally scattered along her sole east and west way, the Ohio. With the three or four east and west lines that are briefly suggested in the sequel, the State will have secured great east and west highways through her borders, which will, in time, do for her what the

great northern routes have done for the region north of the Ohio.

So far from being a barrier, the great mineral belt of Kentucky should be an inducement and a facility for the passage of railways. The industries which must grow up along their lines, the presence of rich agricultural regions at either end of a narrow and not over difficult mineral district, give conditions which are in a high degree favorable to the success of railways. I believe it only wants the careful showing of the conditions, which will be given by a good detailed geological map and the accompanying reports, to bring capital to the construction of these roads. The capital that would be invested in the construction of any one of these roads, counting for nothing the increase they give to the value of land and other profits to the State, would, from its proper taxes, carry the proposed Survey to its completion and completely publish all its records.*

Accepting, then, this basis for action, the question arises, what can be done to get the State before the world in the most rapid and satisfactory fashion? At this moment there is a special need of action. The approaching exhibition at Philadelphia, in 1876, is sure to be taken by all foreign States as a measure of the resources of the several States in this country. The legislative session of 1873–'4 appropriated the sum of thirty-five hundred dollars for the outfit of the Survey, and for the purchase of cases and other expenses at the exhibitions at Louisville, Cincinnati, and at the Centennial Exposition in Philadelphia in 1876. This money has been nearly all expended for the purposes designated in the act. The collections now on exhibition at the Capital are a part of its results. If it is still determined to make some

*At this moment of writing I have a letter from a man in England, one of the many letters that constantly come to me from abroad, seeking to get just such detailed information as to this region as would be furnished by a complete Survey. Capital demands such pilotage, and a State is neglectful of its chances if it fails to give it in as speedy and thorough a fashion as possible.

exhibition of the resources of the State at Philadelphia, it will be possible to double the amount of materials now in the collection, and otherwise to add a great deal to its effectiveness. For this there is no time to spare, the most immediate action being necessary to produce satisfactory results.

In view, however, of the great importance of having something to set forth the character of the State, her resources of soil, the variety and beauty of her surface, I have framed a plan which will, I trust, commend itself to the Legislature as likely to secure an effective showing of the State with the least possible expense.

For the general purpose of illustrating the character of the surface of the State, I have determined to do all that the means of the Survey will allow to make careful photographs, on a large scale, of all the interesting localities within the State, and in this fashion make a record of a great deal of matter of the greatest importance, the truthfulness of which cannot be doubted. By extending this work so as to include the whole of the resources of the surface, we could make an extremely effective showing of the State, the more effective from its rarity. I would have these photographs taken to the number of a thousand or more, of large size, and in the highest style of the art. I would have them give, not only the beautiful scenery, but such a complete picture of the State that every feature of its rivers, caverns, plains, mountains, forests, cultivated fields, cities, and towns should have their place. I would extend it still further, and take pictures of its famous horses and cattle, and of its growing crops, so that the millions who attend the exhibition might be attracted by the completeness of the representation.

On a large map, by a system of numbers, the places where these views were taken could be designated with clearness. I estimate that these photographs could be taken, to the number of about one thousand, during the time that is to elapse before the opening of the Exposition. These pictures would cover the walls of a room one hundred feet long and fifty feet wide, and would form the most effective exhibition that

could possibly be made of the State in the exceedingly short time that intervenes between the meeting of the Legislature and the opening of the exhibition. The actual cost of the making of these photographs will not exceed five thousand dollars for the taking of the negatives and the printing of the necessary number of copies. The expenses of exhibition would have to be added to this sum. I cannot imagine anything more profitable to the State than this photographic survey of its territory. Not only will it serve the immediate purpose of presenting its most important features in a direct fashion to the world at large, but for many purposes of a special kind it will prove extremely useful. The practical experience of the western railway companies has shown that the immigrant will more willingly trust to the evidence when the sun is the witness to the truth of the statement than to any verbal accounts that can be given him. Give him a picture of our soil, of its natural crop of forests and its tillage crops, and we furnish the best possible inducement to immigration. In the practical execution of this plan, I should endeavor to secure a nearly complete panorama of our rivers, and then the character of the surface, as near as possible, by counties, over the whole State. Our caverns, which constitute the most remarkable of the picturesque features of our State, should be shown by about fifty views. The timbering of our admirable forests should be shown with care by many photographs. The scenery in the mountain districts should also receive its share of attention. The great staples of our agriculture, the woods pastures, the crops of hemp, corn, tobacco, &c., should not be forgotten. In a word, the work should constitute a complete pictorial guide to the State. With the photographs, and used as a commentary on them, I should have prepared a general description of the geology and topography of the State, so that the separate pictures might thereby be united into a consistent whole.

Returning to the strictly geological work, I would say, that, in its continuation, it should, as it has done in the past two years, keep steadily in mind the economic development of the

State, not forgetting, at the same time, the great scientific problems which are bound up together with the matters of a profitable nature.

The following subjects are now under investigation, and it is proposed to make them the subjects of other special reports in the fashion indicated in the three volumes of the new series, which are now published or in the press. The following is a general sketch of these proposed reports:

A continuation of the reports on the economic and general geology of the different regions. These reports will include the general geology and coal interests of each section in the two coal fields; along with these, a series of reports concerning the iron deposits in those regions; those industries which connect themselves with iron are sufficiently distinct to require a special series of reports for their representation. Owing to her peculiarly favorable relations to fuel and transportation, Kentucky has a great deal to hope from the large deposits of ore found within her borders; and all this advantage should be set forth with care.

Kentucky has already a considerable industry in building stones; Lewis, Montgomery, and Barren counties especially furnishing a considerable amount of such materials. I have already expressed my high opinion of the Bowling Green marbles. The region furnishing them should be very carefully studied to find the exact distribution of these beds. The Kentucky river also furnishes a series of stones which deserve to rank with the best in this country. The investigation of these stones, according to modern methods, requires the most careful system of tests as to their strength under crushing strains, their endurance of the acids which get into the atmosphere of crowded cities, their resistance to frost and fire, and other qualities. Without cost to the Survey, I have succeeded in constructing a set of instruments well fitted for this particular form of investigation.

Some progress towards a report on the building stones from a dozen or more counties has already been made, and I hope for the publication of its first section within a year. I attach

especial importance to this source of wealth, inasmuch as the rocks of the Mississippi river and its lower tributaries, which are sure to be the seat of a great population, do not afford good building stones, and our State furnishes the best source of supply for the district.

The mineral springs of the State have been for many years the source of considerable profit. After a period of comparative inattention they are again becoming the objects of much interest. The study of these waters should be carried to completion. These researches, in the present state of our science, require a good deal of time and labor from the chemist. The Survey should, owing to the large amount of work during Dr. Owen's administration, be able to carry this work to completion within a short time. I hope to add to the general interest of the investigations by giving a special chapter to all our important springs, and I desire to show the character of their surroundings by a series of illustrations by means of photographs, maps, &c.

The agricultural interests of Kentucky have received, as they should, a special care from this Survey, as well as from that of Dr. Owen, which it continues. This work has been divided into three main sections: the analyses of soils, the analyses of materials likely to furnish good fertilizers to supply the waste, and the analyses of the products of agriculture, with a view to the determination of the nature of the waste caused by each crop.

In these branches of work Kentucky has done more for the advance of scientific agriculture than any other American State. This work, scattered as it is through six volumes of reports, should be gathered together into a single volume. Preparations for this are now going on. Along with this work should go a map, for which a large part of the data are already in hand, showing the agricultural value of the different regions, their several crops, the rate of yield, the differences and capacities of the soils, &c., &c. This would altogether constitute an agricultural geology of the State, and do much

to aid in the settlement of the unoccupied lands which form so large a part of its area.

It will be seen by reference to Volume I, Part I, that the Survey has devised a method of indicating with accuracy the amount of timber of each species found on any area of forest. These forest studies should be extended to the whole State as rapidly as possible, with a view of making a record of the timber resources of the Commonwealth which should have a great effect in attracting those manufactories which depend, in any degree, on the use of wood. These several reports should in the end be united in a general report on the forests of the State. To give this completeness, I am compelled to advise a series of studies on the physical influences of our forests. I have already called attention to the peculiar importance of forests in containing and holding back the rains which, discharged suddenly into our streams, would sweep their valleys with devastating force. The water storage value of forests has been but little studied, and no investigations whatever have been made upon it in this country. To enable the Commonwealth to act intelligently on its own plans of internal navigation, and to solicit the aid of the General Government in the avoidance of floods, I would advise a careful study of this problem. It will cost but little, and will be a creditable and profitable thing for the State to do.

The topographical work should, among other things, be directed with a view to determining the value of our streams as means of securing good water-powers, and as channels which may be improved by slack-water navigation. Incidentally, the matter of storage reservoirs for the retention of water should be examined, as it is important, on many accounts, that this information should be accurately gained. I have already referred to the question of avoiding floods in the districts liable to overflow along the lower Ohio and Mississippi rivers. This should be completely inquired into by the Survey at the earliest convenient time.

In pursuing the topographical work, I have caused meridian lines to be accurately determined by astronomical observations,

and indicated in a permanent manner at certain county towns, with a view to giving an accurate basis for local surveys. This work should be extended until each county town has such a determination, carefully marked by permanent stones fixed in its court-house yard. The need of this as a basis for land survey has been long and greatly felt within the State. This work was done in the State of Ohio by a special survey; it can be done in this State, in the course of the work of the Geological Survey, without any material addition to its expenses.

With reference to the matter of fisheries, I may say, that, while willing to do all in its power, the Survey cannot give any great aid unless the Legislature makes an especial appropriation for the improvement of the rivers by stocking them with various kinds of fish, and for studying in detail the needs of the situation. The sum of twenty-five hundred dollars per annum would enable me to command the services of an expert for several months of each year, and to make the expenditures necessary for more important experiments in this work. It is, in my opinion, better to extend the expenditure over a number of years, pursuing a policy of caution, rather than to run the risk of failure in any large experiments. Unless this course is taken, I deem it best for the interests of the State not to spend any part of the resources of the Survey in the work, for less than the sum mentioned would not produce any valuable results, and would seriously hamper the work of the Survey. I have already expressed my sense of the considerable importance of this work, and I believe that the State would profit largely by having a trained and scientific ichthyologist in charge thereof.

It now remains for me to speak of that part of the work of the Survey which connects itself with the scientific advance of the age, its work in the elucidation of the various problems for which the materials are found within this State. In the preliminary report for 1873, which is contained in this volume, it will be seen that I have fully expressed my convictions as to the duty of our Commonwealth towards science and the part the Survey should take in its advancement. While hold-

ing that the first duty of the Survey was to advance the economic interests of the State, I have also held it equally bound to do all that could be done towards the advancement of those sciences to which we are indebted for the greatest material gains of man. So far I have kept this object steadily in view, and I now feel that the Commonwealth has no reason to be ashamed of the share which it has taken in the scientific work of the day. These scientific memoirs, the first volume of which is, in good part, ready for printing, have cost the State but little; and, with the same generous and disinterested aid of my fellow-workers in science at Harvard University and elsewhere, I hope to be able to go on with the work, and gradually bring all the important problems of the State into a full and careful discussion. The work now planned includes a series of treatises on the fossil organisms of the State; memoirs on its caverns, designed to illustrate their structure and remarkable features; memoirs on their living organisms, &c. The prehistoric remains of the country will receive attention; and as the work of accumulating the evidences as to their character goes on, I hope to see other memoirs added to the interesting paper which occupies a place in the first volume of these memoirs.

Our State is, as I have often had occasion to remark, the river State of America—more great streams lying within her boundaries than within any other State in the federation. I therefore hope to have the extremely important phenomena of rivers carefully studied in our streams. The laws of their movement and the history of their formation connect themselves so easily with the great questions of hydraulic engineering that these researches will not only be a scientific but a most practical contribution to knowledge. The existing organic life in the State, as it gives us a clew to the past history, as well as being an index to the physical conditions of the State, should receive the attention of any complete survey. The great Survey of the State of New York, though begun more than a generation ago, has been a monument to the greatness of the State that planned and executed it. It was

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well worth its cost in the name and place it gave that government. In that comprehensive plan all the natural productions of the State found a place—the plants and animals, recent and fossil, as well as the economic geological resources. This zoölogical study, like the other purely scientific work of the Survey, could count on the aid of the zealous and devoted students of nature for the great and freely rendered services they are so willing to give.

Lastly, the climate conditions of the State: those circumstances of heat, of moisture, of electric and other conditions, and their seasonal and rigoral distribution, should be attentively investigated. On them, more than on any other conditions, depends the character of organic life in all the scale, from its beginning up to man. As these results are only to be gained by averages of many observations extended over a great length of time, it is difficult to bring them within the province of a Survey which is to have a limited life. But a beginning at least should be made, observations should be solicited from citizens of appropriate opportunities and fitness, who are willing to contribute something to the study of the State. These observations could be continued after the work of the Survey was done by some fitting bureau; for instance, a bureau of statistics, should the State ever meet this great need by creating such a department.

I cannot forbear to speak of the importance, in a thorough survey, of carefully collecting the vital statistics of the State. In the higher sense of geology, this, too, connects itself with the science, though it should be sought by some other means than such an organization as a Geological Survey: a statistical study of the State could use the work of the Geological Survey, and incidentally would throw great light upon some of its most important questions. I believe that the conditions of soil and climate found here are peculiarly fitted for the best uses of man, and I believe that a system of vital statistics, which should be extended, if possible, to all the questions that have value in determining the vital conditions of the race, will be of great value to the Commonwealth.

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GEOLOGICAL SURVEY OF KENTUCKY.

N. S. SHALER, DIRECTOR.

NOTES ON THE INVESTIGATIONS

OF THE

KENTUCKY GEOLOGICAL SURVEY

DURING THE YEARS 1873, 1874, AND 1875,

BY N. S. SHALER.

PART III. VOL. III. SECOND SERIES.

NOTES ON THE INVESTIGATIONS OF THE KENTUCKY SURVEY.

INTRODUCTION.

In the following notes the general scientific work of the Survey and its most important conclusions will be briefly discussed. It is the intention of the collaborators of the Survey to bring most of these matters under more extended discussion, in the form of special memoirs or reports. They are given here with a view to setting forth the nature and progress of the work under consideration. The problems connected with the geology of the State will be first discussed, and then the questions of a more general nature.

Owing to the fact that the whole of the system of rocks found in Kentucky lies above the level of the Potsdam sandstone, and is practically limited to the Paleozoic series, the problems in stratigraphical geology are quite limited in their range, though of very great interest. The questions of a dynamical character are more numerous and connect themselves more extensively with the general geological history of the continent. The Appalachian system of dislocations is represented within the State by an extensive series of disturbances. The erosion phenomena of the country are extensive and varied, and should receive close study. The question of the origin of the sediments which compose the rocks of the State present other problems, the solution of which will aid in the understanding of many of the questions concerning the past history of this continent.

It is, however, in the history of the course of organic life that we find the most noteworthy matters—those which give the most important and attractive series of facts. In that history we have recorded the course of events from the time when this region lay at the bottom of an exceedingly deep sea,

through successive changes, leading to greater and greater shallowing, until an infirm land was established at the time of the coal—these great swamp forests, alternating with the successive invasions of the sea; after that a vast and unrecorded time, when the principal events happened on the land, and therefore want the records of that great historian, the sea. The changes of life which accompanied these changes of physical conditions must always afford great problems for the student.

In the following pages many of these problems will be little more than stated, few or none advanced to the point where they can be regarded as having had their last word. Not the least reason for their statement is the hope that it may arouse our students to a sense of their importance:

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CHAPTER I.

The Kentucky series of rocks, as has already been stated, extend from about the top of the Calciferous series, which are the lowest rocks exposed above the drainage of the country, up to and including the lower half of the Carboniferous series. In the western part of the State there is a great covered district, where we have exposed some beds of a Tertiary deposit, belonging, doubtless, to a very late stage in the earth's history, and which is provisionally classed by the Survey as early Pliocene. Between this carboniferous section and the clearly exposed beds along the Mississippi river, we have a considerable interval where the beds are mostly concealed beneath the drainage. In this area, probably at no great depth, we most likely have several other deposits of earlier Tertiary and Cretaceous age; below these the Carboniferous system and the refined beds extend, doubtless, across the whole of the swamp region, and probably within a few thousand feet, possibly within a few hundred feet, of the surface.

The continuity of the Kentucky series was unbroken from the time of its commencement to the close of the Carboniferous, and probably later, by any change so momentous as to bring the condition of extensive dry land within its borders. After that time of emergence there is no evidence that the sea ever came to occupy a large part of the State. A general consideration of the geology of North America shows us that the Kentucky rocks are only a small and not distinctly limited fragment of a series of formations which may be termed the Mississippi series, though they were mostly formed before that valley had a distinct existence. It will, therefore, often be necessary to pass beyond the limits of the State in order to obtain clews to that which may be hidden within its limits.

Looking into other parts of the Mississippi Valley, we find that there have been extensive deposits, formed at various points, which are of a date much later than that of the carboniferous limestones, and yet older than the clay beds of the Hickman series. These beds of the Permian, Triassic, Cre-

taceous, and early Tertiary age, come in as we go either to the westward, where they all are found covering considerable areas, or to the southward, where only the last two series appear at the surface. The presence of these deposits within the division of the continent to which Kentucky belongs, may fairly entitle us to ask whether they had been deposited here, and afterwards worn away, or whether they were never laid down over this region. This point has never been carefully considered; and as its determination is a matter of considerable importance, we will have to discuss it in some detail.

The first point requiring attention is the fact that this region is being worn down at a relatively rapid rate. The data for fixing the precise average down-working of the surface have not yet been determined, but a study of the facts obtained by the researches of Humphreys and Abbot for the Mississippi river will enable us to approximate to a satisfactory conclusion. The conclusions based thereon are to the effect that the Mississippi discharges from its mouth, in the shape of dissolved mud and coarser sediment, pushed along by the current on the bottom, matter enough to form a stratum one foot thick over the whole surface of its valley in about seven thousand years. To this total the several sections of the valley contribute very unequally. The rain-fall of the several regions varies greatly, and the region occupied by Kentucky has at present far more than the average rain-fall. The data for a very accurate determination of these points do not yet exist; but enough is known to enable us to say that, area for area, the Ohio Valley yields about twice as much sediment as the Missouri Valley; so that one foot in depth in about three thousand five hundred years has probably been about the rate of the erosion of surface during the time immediately antecedent to the present day.

Nothing in the physical conditions of the earth is so variable as the rain-fall in particular districts; every uplift and downthrow of land on the earth's surface, if it be considerable, must propagate its efforts throughout a hemisphere; but we may with safety assume, that, ever since the Rocky Moun-

tains were formed, the relative rain-fall of the two regions represented by the drainage basins of the Ohio and Missouri has been about the same. Whatever would tend to increase the rain-fall of the Missouri district would probably tend to bring up that of the Ohio. There is nothing in the way of changes in the past, so far as we can see, which could have tended to lower the rate of rain-fall, and consequently to diminish the rate of erosion in the Ohio Valley; on the contrary, as I shall endeavor to show in the fourth chapter, the last recognizable change brought diminished rain-fall, and that for a period of many thousand years, this region was the seat of a precipitation far more active than at present. No definite weight can well be given to this fact; but it doubtless serves to show that the estimate of erosion given above is probably not excessive. Assuming, then, that each million years will take away about three hundred feet from the surface of the country, the question arises, how much time has elapsed since the Carboniferous period was completed—the last of the general formations of the State. The science of geology has never attained to that accuracy which will enable us to give definite answers to such questions; but certain general estimates have been made which probably have a certain value. Without digressing into a discussion of these methods, we may say that those geologists, who have attentively studied the natural records of the earth's surface, would all agree that the Carboniferous period must have closed at a time certainly more than ten million, and possibly more than twenty million, years ago. Without attaching too much value to these estimates, we see that something over three thousand feet of beds must have been worn away from the surface of this region since they were uplifted above the sea level. The only way in which this conclusion can be greatly limited is by the time to be allowed for the deposition of the beds which have been lost by erosion. This may much reduce the amount of the erosion; but it must still leave it probable that a great thickness has first been deposited, and then eroded from this region, since the Carboniferous time.

Many reasons concur to make us believe that this additional thickness of beds was on the whole principally of Carboniferous and Permian ages. These reasons are substantially as follows: The greatest single movement of the Appalachians in their uprising was at the close of the Carboniferous time. Now, there are many reasons for believing that this extensive flexing of that chain was accompanied by a general uplifting of the whole continent, or at least that broad western sloping table-land which lies against the Appalachian Mountain system, and is in effect the table-land element of that chain. Furthermore, the Mississippi Valley, at least its central section, seems to have moved tolerably together in its upheavals and subsidences since the beginning of the sub-carboniferous limestone. Moreover, in western Pennsylvania, we have a thousand feet or more of beds, which lie on top of the topmost part of the Kentucky section, and in the Missouri Valley we have an extensive series of Permian deposits, which may well have lain on top of all we have in Kentucky and Pennsylvania. These beds may well represent the section which has vanished in Kentucky, as a consequence of continued erosion. It is possible that other sets of rocks may have rested on the top of these—the uppermost beds of the Paleozoic series; but I think it quite unlikely that this part of the Mississippi Valley has been resubmerged, and the seat of marine accumulations, except on its extreme western border, and this only to a slight extent.

There are in the Southern States, about the Gulf of Mexico, vast deposits of detrital materials, which are probably the waste from the upper Paleozoic rocks and underlying formations, of the exposed parts of the continent. Owing to the peculiar position of these regions, it is difficult to see any other source for their deposits than this northward-lying section of the North American continent. These beds, in their turn, have been greatly wasted; but enough of their mass remains to represent some hundreds of feet in thickness of beds over the whole of the Mississippi Valley.

There are some peculiar features in the organic life. The gar-pikes of the Mississippi system of waters, though extending, it is true, eastward to Lake Champlain, may be regarded as essentially characteristic of this river system of the central valley of the continent. This form is fully recognized by naturalists as a relict of an earlier assemblage of life, which was generally extinguished at the close of the Paleozoic time, and has only survived in corners of the earth since that time. If the whole of the water system it inhabits had ever been submerged at the same time, it is reasonable to presume that this race of animals would have been exterminated. It is, therefore, fair to presume that there never could have been conditions suited to the formation of extensive deposits, covering the whole valley, since the carboniferous period, or thereabouts. There is another piece of evidence likewise derived from the organic life of our rivers, but in this case from a group of mollusks. The unionidæ, as is well known, have a very extensive development in the Mississippi Valley, especially in its Ohio waters. The diversity of species in this section much exceeds that which we have in any other region; indeed, it seems likely that there are more species to be found in these waters than could be found in all the other waters of the world. The only conclusion to which we can come is, that the group has been freer from the invasions of the sea in this region than in any other, and that here, as in the case of the gar-pike, the necessary conclusion is, that the forms have been from a very ancient date safe from the invasions of the sea; the great lapse of time having given an opportunity for great increase in the number and the variety of species. Something of the same nature may be concluded from the character of our American forests. Many genera, which have existed in Europe during the Tertiary era, have died out there, and only remain in existence on this continent. This is notably the case with the genera *Liriodendron*, *Liquidambar*, *Nyssa*, &c.

These genera are now peculiar to our Mississippi Valley and other neighboring forests, but they once flourished over central Europe. Invasions of water, and probably also of ice,

have served to extinguish these forms there, while in America they have withstood the dangers of time, and remain little changed over a great period. This immutability can best be explained by supposing that this region has remained in great part unsubmerged.

The caverned regions of the State are in themselves enough to assure us that there has been no great submersion of the region during the last million or two of years. Any such submersion would be necessarily attended by very great changes in these wonderful structures. They would probably become closed to a great extent by marine deposits, while the superficial marks, which would be made by a short occupation of a country by the sea, might be effaced by the erosion of a million of years, or even less. The cavern record ought to last a good deal longer.

While denying that the general surface of Kentucky has been beneath the sea since the Carboniferous period, we are driven to acknowledge that the western section along the Mississippi has been so far depressed that it has been able to accumulate beds, having a thickness of at least three hundred feet above the level of the river. From an imperfect examination of these beds, I am inclined to think that they were rather fluviatile than marine in their character. Yet, I am disposed to think that they were nearly on the level of the sea at the time of their deposition. It must also be noticed that inasmuch as these beds wear with considerable rapidity, the million of years which must have elapsed since their formation may have been attended by a loss of over one hundred feet in height. A sea carried over the country to the height of one hundred feet above the bluff at Columbus or Hickman, would extend over the State for a considerable distance to the eastward. By our conditions, it would meet a higher country in that direction, owing to the loss which has taken place over its general surface during the time which has elapsed since the close of this subsidence. It seems likely that the eastward line of such a sea, assuming it to have been created by a general and not a local subsidence, would have fallen east of the Tennessee river; and that along

the Ohio and other rivers it should have penetrated some hundred of miles further. The entire and well established absence in these basins of any such deposits is a striking and nearly complete evidence of their local nature.

It is not to be believed that, in the many sheltered nooks, where they could have been preserved by favoring conditions, they have all been lost, while in the very line of the Mississippi, exposed to repeated assaults of one of the most destructive of streams, they have alone survived. It is easier to suppose some local and peculiar forms of elevation, acting at this point, than to suppose the total destruction of all the other fragments of a great even sheet, except these detached and exposed masses. There must have been a considerable area of this elevated country, but it could hardly have had the extension which we would naturally have expected from its considerable altitude and its general character. It may be that there is some connection between the formation of a rather local series of elevations in this district and the occurrence of strong disturbances, such as that known as the New Madrid earthquakes, in 1811–'13. At that time we had in the region of Reelfoot Lake, as we shall see in the subsequent chapter, a down-sinking of a great district to the amount of ten feet or more. An uprising similar in its origin may account for these remarkable insular masses of elevated land.

It may be well observed, that if these masses had been part of an equal level plateau, the deposit should have filled up a large number of the Green river caves, and would have barred the northward course of the Tennessee and the Cumberland rivers by filling their valleys. As it is, the supposition that these Hickman and Columbus ridges are part of an ancient local elevation, would enable us to account for the fact that the Cumberland and Tennessee rivers flow so far to the north and join the Ohio rather than the Mississippi, towards which the general direction of the drainage should direct them. Such a barrier may have turned river courses to the northward and maintained them there until their new beds had been formed.

The next question as to the prehistoric changes of Kentucky is concerning the original horizontal extension of the several formations found within the State. An inspection of the accompanying geological map will make it plain that there are at present two distinct areas or geological basins, as they may be called, which lie within the State: one of these is the eastern coal field, and the rocks which lie below it, and the other the western coal field and its little-known underlying rocks. The barrier which separates these fields is the long low ridge sometimes known as the Cincinnati axis, but which ranges from the State of Alabama on the south to central or northern Ohio on the north. This axis has some important features which throw no little light on the general dynamics of the North American continent. In a subsequent chapter its character will be extensively discussed; it is only necessary for us, in the present connection, to determine when it was formed and to what extent it separates the region on the west from the east. The diagrammatic sections in this report will serve to show its general relations to the rocks on either side. It will be noticed in the maps, that the several formations of the State show escarpment faces turned towards this central ridge, and the student in the field will readily perceive that these erosion faces are steadily retreating from the central part of this ridge. He will also perceive that the ridge itself has certain peculiarities which separate it from all ordinary mountain ridges. It is singularly wide, being at least fifty miles across, and very low, not rising more than three to four hundred feet above the general plain of the Ohio valley.

A careful study of this ridge has convinced me that it was begun at a very early day. The beds exposed at the level of the Ohio opposite Cincinnati show a good many pebbles of limestone rock imbedded in the limestone and shale. At the same point, and in the overlying rocks, for one hundred feet or more of height, the beds show occasional layers of broken shells packed together as by strong currents. This is especially noticeable in the beds containing *Strophomena alternata* which occur throughout this section. These facts point to

the conclusion that these beds were formed in shallow water, and that this shallow water was swept by strong currents. Beneath the Cincinnati Group there is an extensive system of sandstones or other quartzose rock. This is shown by the matter brought up by boring made near Cincinnati, which I examined in 1868, when, from the depth of two hundred and seventy feet below the bed of the Ohio river, the auger brought up a fine silicious rock, seemingly the fragments of an open-grained sandstone. From this rock, and from the beds just over it, issue a great number of saline springs, which occur all along the Cincinnati axis. There is no other way of explaining these springs save by supposing that they are flowing from deposits of salt laid down when this region was near the surface of the water, so that great salt marshes were formed, to which the sea water had but difficult access, so that, by evaporation, quantities of salt were laid down. These several facts—the occurrence of salt deposits at one level, pebbles at a point some hundred feet or more higher, of broken shells at yet another hundred feet up in the section, and finally of salt deposits again in the blue-grass limestone, which forms the summit of the Cincinnati Group—gives us fair reasons to conclude that this series of deposits was formed in a region which was balanced near the top of the ancient seas. On the other hand, on the east, in the region now occupied by the headwaters of the Tennessee, the beds deposited at this time were all made in deep water, without any of the phenomena which indicate occasional elevation of the bottom to the surface. I have not personally examined the equivalent beds in Illinois, but I believe from the descriptions that they likewise fail to show these alternations of condition which indicate shoal water. Even the equivalent beds in New York, although formed near a shore line, fail to show anything like as much evidence of the successive uplift into land conditions of that region as is shown about the Cincinnati axis.

Along with the evidence already cited to show the ancient character of the Cincinnati uplift, we may cite the extraordinary frequency of sandstone beds at some points in the series,

particularly at about one hundred feet below the top of the section. This shows that the shore line probably came near to this region a number of times when the bottom did not actually arrive at the surface.

The Cincinnati series in this section is closed by a sandstone, ranging from five to fifty feet in thickness, entirely barren of organic remains. The history of this rock is not easy of determination, but it is peculiar to the Cincinnati axis, and marks one of those sharp transitions which are so prominent a feature in this section, indicating the rapid successions of upheaval and subsidence which resulted in giving us a broad irregular mountain fold traversing the State.

The existence of recurring upheavals since a very early time makes it doubtful when this axis of elevation came above the sea so as finally to interrupt the deposition of strata. It was at first assumed by geologists that the beds of the carboniferous and all the underlying strata down to the base were laid down continuously over the whole of the Cincinnati arch. More recently it has been announced, with almost equal want of definite proof, that the elevation has existed from a very ancient time, and that the eastern and western coal basins were deposited in areas which were separated by high and dry land, in this region. In both these conclusions no reference has been made to the erosion rate of the surface, nor any attempt to reconcile the conditions of this action with the theories on which they rest.

The sections given in this volume show us that the Cincinnati Group is continuous over the arch at points where the cutting is deepest. They further show that the upper Silurian continues over a large part of the area in a more or less fragmentary way: its waste is found on the tops of some of the highest hills as detached outliers. Above this comes a very soft formation, the Devonian black shale or Ohio shale, as it will be called in these reports. The absence of the outliers of the Carboniferous and Waverly series is, I am inclined to think, dependent on the softness of this bed, and the rapid destruction which would overtake outliers which rested upon

it. This accounts for the tolerably continuous front of the Carboniferous series in northeastern Kentucky, where this bed is thick, and the increase of outliers in the southern section of the western front of the eastern coal field, where it is thinner. The more rapid retreat of the beds away from the Cincinnati end of the axis than from the region penetrated by the Cumberland river is, in part at least, doubtlessly due to the greater thickness of this formation in the region along the Ohio river, and the consequent more rapid wearing back of the escarpment. If we allow that one hundred and forty feet of beds wear off of this region each million of years, then, at that distance in the past, we had the whole of the Niagara Group stretching across the arch at Lexington, and covering almost the whole of the arch throughout its extent from Cincinnati to Nashville. The only sections which would have been cut deeper would have been the stream beds themselves. Another million of years into the past would give us the Ohio or black shale over the greater part of this area. We would probably have to go something like two millions of years further back to find the time when the greater part of the Waverly series still rested on the whole of the summit of the Cincinnati axis. This is only taking the average rate of wear for the Mississippi Valley. We have seen that it is more probable that the rate for the Ohio Valley is nearer three hundred feet in a million years. On this basis it would only be necessary to restore the wear which has taken place during the last two million of years to return to the Cincinnati axis all the beds up to the sub-carboniferous limestone, over the region where now the surface is cut down to the Cincinnati Group. The same method of determining the changes of the past would lead us to conclude that, between four and eight million years ago, the surface of the country over the Cincinnati axis lay within the coal-bearing rocks. There are only two conditions which could essentially invalidate this reasoning. There may have been other beds laid over this region which have taken the brunt of the wear, or the rate of erosion has been on the average less rapid

than our hypothesis supposes. The first of these objections seems to me to have little weight, inasmuch as the wide expanse of country that must have shared this deposit has failed, on narrow search, to reveal the slightest trace of any such beds in any of the valleys or other places where it might have been sheltered from the erosive actions which destroy the geological records.

This absence of even fragmentary remains is always a very decisive circumstance, tending to show the non-deposition of any particular beds in any given district. Such non-conformable beds are apt to last longer than any single element of a series, on account of the greater variety of conditions under which they have been deposited. The other possibility in the way of the general conclusion as to the beds which have been eroded is, that the rate of wear may not have been, on the average, as great as that which has been supposed in our computations. To this it may be said, that not only is the time a low estimate, but it may also be fairly concluded that, during a large part of the past, the rate of wear was materially greater than at present.

Before leaving our consideration of the Cincinnati axis I desire to say a word concerning the age of its formation. We have already seen that during the later Cambrian time it was in a state of constant oscillation. If the evidence is read aright in the foregoing pages, these oscillations seem to have left it, at the time of the last deposits of the Cincinnati Group, still well depressed beneath the water; for the Cumberland sandstone, which lies on top of that series, is never mixed with pebbles, and could not have been deposited except at sufficient depth to have secured a tolerable uniformity of conditions. If this axis had furnished shore lines during any part of the time occupied by the formation of the succeeding beds of the Silurian, Devonian, and Carboniferous periods, we should expect to find some indications of the fact in the existence of pebbles derived from these shores. The Devonian black shale, it would seem, ought to show a certain amount of calcareous material in those portions of its area which come

near to the axis. The absence of such deposits may possibly be accounted for by the stillness of the waters in which these beds of the Ohio shale were laid down; but in the Waverly series of rocks we have a great thickness of deposits composed of sand, which show currents strong enough to transport materials from a great distance, but no trace of matter which could have come from the Cincinnati axis. Moreover, if it had supplied large quantities of detritus it would cause all the beds deposited against it to thicken as they approach it. No such indication can be discerned. The Carboniferous Conglomerate, on the contrary, increases in thickness as we recede from the Cincinnati axis. It contains great quantities of pebbles, both in the east and in the west, but not a trace has yet been found of any pebbles which could be attributed to the Cincinnati axis. The mountain or sub-carboniferous limestone passes across the axis in the low section between Nashville and Cincinnati, making what is known on its escarpment as Muldraugh's Hill. This part of the field must have been quite near the ancient shores, if there were any, as it is not over fifty miles from the highest point on the Cincinnati axis. Yet this deposit shows here the same evidence of remoteness from shore lines, whence detrital matters could come—the same evenness of texture and absence of those alternations of materials which always mark shallow water beds.

Along the Cumberland River section the inferior measures of the coal series in the east and west approach so closely to each other that it is said to be possible, in very clear weather, to see across from one section to the other; the high outliers of the Carboniferous system supplying the intermediate links, so that the actual break between the coal fields is probably not more than forty miles. The replacement of one hundred and fifty feet of beds which have been worn away would probably unite the coal fields of the east and west by making the lowest beds of coal, which, as we shall see in another chapter, come in the upper Chester series, continuous across the whole central region of the State. It is impossible to resist the con-

viction that a million of years or thereabouts ago this section still contained a continuous sheet of coal reaching from Wayne and Clinton counties on the east, across to Edmonson and Hart on the west.

I believe that the uppermost level of caves which remain open in this region were formed during the time when the hills of this section were still so continuously capped with the remains of the coal fields that there could have been no doubt as to the continuity of the two fields—the eastern or Appalachian, and the western or Illinois field. This original continuity being granted, the most material question as to the relations of the two coal fields is substantially disposed of. Going north or south of this line, more and more time for the erosion becomes necessary, for that erosion increases progressively, until at Nashville or Cincinnati we require a duration which is probably somewhere between four and eight million of years for the completion of the down cutting from the true coal measures. Although the discussion of the dynamic geology of the Cincinnati axis must come in the fourth chapter of this report, there are some reasons why we must prolong the consideration of it here until we have determined, as well as we may, the time of its formation. Inasmuch as there are facts going to show that there were successive upheavals along the line of that axis at a very early day, viz: in the time of the Calciferous Sandstone and the succeeding ages up to the upper part of Cambrian, I am inclined to believe that the upheaving action began in this region at the beginning of the time before mentioned. But, inasmuch as this whole region seems to have been depressed beneath the sea during the period when at least one thousand feet of successive beds were forming, it is difficult to escape the conclusion that this elevation could not have been very considerable, and must have either been quite effaced or have been borne down by a subsidence of the whole continent, so that it made no obstacle to the uniform deposition of beds.

It is difficult to form a satisfactory opinion as to the time of the last elevation of the Cincinnati axis. The most noticeable feature is, that, while the Cincinnati and Nashville sections of it are geologically three to four hundred feet higher than the section lying between Wayne and Hart counties, yet these two first named regions are cut even lower than the section lying between them. If the ridge had been elevated with anything like the suddenness that has characterized the upheaval of many mountain ridges, the several rivers that traverse it would have shown more indications of disturbance of their courses than they exhibit at present. They are, however, not altogether wanting in deflections, which show their contact with the axis—the northward inclination of the Ohio—all the way from the mouth of the Chatterawah or Big Sandy, until it makes an angle on the summit of the axis at Cincinnati. The sudden bends in the Kentucky, in passing through Madison, Fayette, Jessamine, and Garrard, may be due to the changes brought about by the elevation of this axis. That of the Kentucky river is doubtlessly, in part, due to the Dix river fault and the associated dislocations, all of which are probably due to this fold of the Cincinnati axis. The southward bending of the Cumberland, in Pulaski county, is more distinctly the effect of this axis. In its course, this stream shows something of the same peculiarities as belong to the Ohio: they both turn away from the general trend of their basins, in what appears to be an effort to avoid the central region of the axis, and, after passing it by, return at once to their normal courses. While feeling much doubt about the conclusion, I am, on the whole, inclined to think that this axis has been the product of a number of successive elevations rather than a single upheaval; and I am furthermore inclined to believe that the principal part of this uplifting came after the close of the Carboniferous time.

CHAPTER II.

In this chapter I shall consider the succession of the Kentucky series of rocks from their lowest to their highest members. A great deal remains to be done before the whole of this history can be gathered, but its general outlines are tolerably well known. While much that will be given in the sequel is already well known from the study of other western rocks, there are many points which are now discussed for the first time, and have the light of the observations of the present Kentucky Survey to aid us in our understanding of them.

Owing to the comparatively undisturbed character of the Kentucky rocks, the area of the State does not give us a single point where we can see deep into the more ancient part of the section of the stratified rocks. The appended diagrammatic section will show how small a part of the beds above the rocks, which show no distinct trace of having been laid down from water, are exhibited within our limits. It will be seen that not more than one tenth of the total section lies exposed in Kentucky, and that there are probably something like forty thousand or more feet of rocks deposited in ancient seas, and still retaining some trace of their stratified character, that lie hid beneath the surface of the geologically lowest regions of the State. In making this ideal section, I have taken the sections as given in Canada and in the East Tennessee section. In both of these regions we have great depths of rock exposed. The rocks for some eight thousand feet below the surface are determined from the East Tennessee section. Those from that point downwards are taken from the known rocks of Canada and the northern part of the Appalachian system. It should be understood that below the level marked Potsdam sandstone the section is quite doubtful, although it expresses the best known probabilities of the case: above that level the East Tennessee rocks, with incidental corroboration from the peculiar elevation described by Professor J. M. Safford, at Well's river, near Clarksville, Tennessee, afford what seem to me tolerably trustworthy data for conclusions concerning the underlying beds of Kentucky.

I have already noticed the fact that the well bored near Cincinnati brought up a silicious shaly sandstone from a point about two hundred feet below the lowest level shown in that neighborhood. This corroborates the conclusion that this East Tennessee section is, in a general way, similar to that at Cincinnati, for, beneath the Cincinnati Group, in the Powell Valley, we have a similar silicious shale, known in Dr. Safford's report as the Knox shale. It should be noticed that the East Tennessee section is far thicker than that at Cincinnati. The six hundred and fifty or seven hundred feet of the Cincinnati Group becomes fifteen hundred feet in the section at the foot of the Cumberland Mountains. We may reasonably anticipate a similar thinning of the beds lying still lower in the section in Central Kentucky.

Leaving the doubtful regions lying below the light of day, and coming to the beds which are disclosed in the natural section, we find ourselves in some doubt as to the point where the lowest beds are to be found within the State. The sections at Hickman Landing, on the Kentucky river, and at Cincinnati, both offer us exposures which extend to low points in the series. By a comparison of the sections given herewith, it will be seen that the bottom beds exposed at these points vary considerably.

It has generally been assumed that the beds at Cincinnati are somewhat lower than those at Lexington; but I am inclined to think that a fair judgment on this matter will lead us to very different conclusions. At Cincinnati the beds containing *Isoteles gigas* are found in the bed of the river; and in all my study of these rocks, which has been long continued, I have not found a single specimen of this form above the level of high water mark at this point.

Without attaching too much importance to the indications from a single species, I may say that the occurrence of this same fossil on the level of the city of Lexington, more than three hundred feet above the corresponding height at Cincinnati, has made me doubt the truth of this assumption of the higher geological position of the former place. It will be seen

that the series at Cincinnati, beginning with the argillaceous limestones, containing *Isoteles gigas*, is continued by a series of beds containing, among their most characteristic fossils, *Trinucleus* (*n. sp.*), &c. Just above these, and during the time of the disappearance of the genus *Trinucleus*, come fragmentary *Calymene, Orthis testudinaria, Plectambonites sericea*. The higher beds, certain parts of the section lying within one hundred and fifty feet of the Ohio river, at Cincinnati, contain an abundance of *Chætetes*, but always of the *lycoperdon* type, never of the *C. petropolitana* variety. At about two hundred feet above the river *Platystrophia lynx* becomes abundant, and *Strophomena alternata*, which has been represented by rare and attenuated forms—the horizon of the *Isoteles gigas*—becomes very large and distinct. In the Kentucky River section we have no such order of succession of species. The beds, as will be seen by the section, begin by marine, dove-colored, and whitish marbles. These contain no organic remains except the obscure fossils which give the "bird's-eye" look to the mass. After rising through a series of these we come to a level where there is a good deal of shale in rather thin partings. Some of this shown at Frankfort, only a few feet above the top of the "bird's-eye" bed, is of a light green color, apparently owing its hue to a coloring of phosphate of iron. This deposit is analyzed in Dr. Peter's report, and might have some economic value were it not for its thinness.

The next noticeable feature is the occurrence of a bed quite filled with several species of *Orthoceratites*, and containing some specimens of a species of *Conularia*, neither of which have I ever seen at Cincinnati. In no part of this section have I ever found *Isoteles gigas*, or the *Trinucleus* found at the Cincinnati localities, at the same absolute height;* nor in ascending higher do we get into much more familiar associations. The next step upwards brings us into the beds especially characterized by the *Chætetes petropolitana*. Several familiar fossils occur on this level, but they are forms which have tol-

*The term *absolute height* is used to indicate height above the sea level, and is used in contradistinction to relative height, or height above a certain geological level.

erably wide ranges, and they have enough of local peculiarities to enable us to say that they are varieties due to peculiar conditions. As we ascend to the top of the bluff at Frankfort, we come, near the top, into a tolerably familiar assemblage of fossils, which seems on the whole to represent the level found at about two hundred and seventy-five feet above the river at Cincinnati. About the level of the uppermost point in the section at Frankfort we have an important bed, whence have come a number of remarkable fossil sponges. A very curious form, shaped like a candelabrum, briefly mentioned by Dr. Owen under the name of *Scyphia digitata*, seems to occur in this bed, though the several specimens which have been found have never been seen by a naturalist in their original position. This species is only known from the waters of Benson Creek, near Frankfort. I find another species of remarkable form in this level in Henry county (found on the surface). Near Lexington, in what seems to be the same geological horizon, another species occurs, which resembles nothing else so much as a fossil artichoke. This form is very abundant on a small exposure, not exceeding half an acre in area; bushels of weathered specimens could be gathered. No such sponge-bearing level exists in the neighborhood of Cincinnati.

I do not mean to discuss at the present time, in all its bearings, the question of the relation between the Cincinnati section and that at Lexington; for the field work of the Geological Survey cannot be said to have begun in this area. I only desire, in a preliminary way, to suggest that a question exists as to the parallelism of these sections, and that it is an important one for the geology of this district. Either of two conclusions are possible, that the section essentially represents the Cincinnati Group in a geological sense, having been deposited at the same time, or it overlaps it on one side or the other, lying, in whole or in part, above or below it. If the first supposition be true, we must suppose a change of an important kind in almost every element of the section in passing from Cincinnati to Lexington. The other supposition may

seem much easier, but we shall find it cannot be well reconciled with the evidence. Near Mt. Sterling, rocks, which seem immediately to overlie the *Isoteles* beds at Lexington, and to be not over fifty feet above them, are in turn overlaid by the beds which we have found within the Cincinnati series, and which are termed the Cumberland sandstone in these reports. Dating downwards from this sandstone, as it is found near Mount Sterling, we must consider the Lexington beds as the equivalent of the ~~highest~~ lowest beds at Cincinnati. The only doubt is as to the existence of a considerable fault between Lexington and Mount Sterling. The beds seem to have no very strong dip in passing from Lexington to Mount Sterling, so that I cannot well suppose a difference of elevation of as much as a hundred feet between the two localities. A careful examination has failed to reveal any signs of a fault between the two points. The existence of a considerable break along the Kentucky river may be regarded as giving a basis of suspicion that we may have something of this kind at Lexington; but there is no good reason for the supposition that there may be a dislocation bringing up the Lexington rocks to a greater height than they would otherwise have had. The work of making detailed sections across this field in several directions, which this Survey now has in hand, will give us the basis for an accurate determination of these points. For the present, it will be best to assume that there is a tolerably accurate correspondence of level between the Kentucky river section, near Lexington, and the section at Cincinnati, the great difference in physical character and in fossil contents being due to the action of some local causes, the nature of which is not well understood, but is probably referable to difference in the depth of the sea when the beds were deposited. On this supposition we will have to allow that the Cincinnati section shows far more alternations in physical conditions than the section at the Kentucky river.

The Cincinnati section gives us many more shales, several distinct, though thin-bedded, layers of sandstone, which are not

represented at Lexington, though some few sand layers occur there, and the beds of broken shells which do not occur in Central Kentucky. On the other hand, Lexington has the peculiar upper level of *Isoteles gigas*, the remarkable sponge bed before described, and several other peculiarities which I will not discuss here. There is also an important mineralogical difference. The upper beds at Lexington are charged with saline materials, and give rise to springs clearly resembling in general character the waters which rise at Big Bone Lick from a level beneath the drainage of the country. This is, to my mind, a suspicious circumstance, inasmuch as I have never seen any evidence of the occurrence of these rock waters in the upper levels of the region about Cincinnati. Moreover, the Lexington series of rocks is penetrated in various directions by veins of sulphate of baryta, containing considerable quantities of galena. This galena district does not extend as far east as Mt. Sterling, but lies between a line running from near the middle of Clark county, thence by Georgetown to Henry county, and the line of the Kentucky river. Whether their differences be due to faulting or local peculiarities of deposition, these two regions must be regarded as presenting problems of great interest, which it will be the duty of the Survey to consider.

Taking the Ohio River section as the typical section for the State, and leaving the Kentucky River district out of consideration on account of the doubt which exists concerning its precise position, we arrive at the conclusion that, between the lowest level above the drainage and the Cumberland sandstone, which closes the Cincinnati series, there is a tolerably continuous succession of life from the lowest point seen up to the top of the series. There are certain changes, however, and I have as yet failed to see a single species, except it may be a *Lingula*, which continues quite unchanged from the bottom to the top of the series. The section excavated at the bottom of the channel at Cincinnati seems to mark the top of one association, determined, it may be, by the conditions which made a very argillaceous limestone, intermixed with

blue clay, the principal element in the series above these beds at the level of the ordinary high water. Above this point we have a series of massive limestones, very encrinoidal and remarkable for the occurrence of a species of *Agelacrinites*. Above that point there is another series of shales, alternating with limestones, generally with their layers extending up to about two hundred and fifty feet above high water mark. At this point we begin to have a series of arenaceous layers coming into the succession of limestones and shales, and the shales lose, to a certain extent, their blue color, becoming whitish or clay-colored.*

Whenever, in any succession of beds, a series of limestone layer is followed by a sandstone, there is generally a considerable change in the organic contents of the beds, and where, as is often the case, the limestones return again, the interrupted succession of life is rarely restored in its original shape. Most of these beds of argillaceous and calcareous sandstone, the "silicious mudstone" of Dr. Owen, contain some fossils. These are, however, generally small, and are found in no great abundance. Most of the species living in this sea when the deposit of the arenaceous beds began were apparently driven away, and when they returned at all, returned with much altered shapes. Neither in nor above this level have I found the *Trinucleus, concentricus, Isoteles gigas, or Plectambonites sericea.* After it came a swarm of other forms new to the seas of this basin. The history of the details of this change is not yet prepared, but it is sufficient for our purpose of tracing rapidly the physical history of the sediments of this basin to notice the occurrence of the arenaceous level at this point, and also to notice that it makes a considerable organic break in the series. I am satisfied that there are the following distinct organic sections in the Cincinnati Group, as exposed at Cincinnati.

The first of these is the set of very blue argillaceous limestones in which the low-water bed of the river lies, and which

* On page 171 of Dr. Peter's report (vol. 1, new series) will be found an analysis of some of these light-colored or sandy-colored clays, from which it will be seen that they are in marked contrast to the blue lower-lying clays.

extends from forty or more feet below the low-water mark to about fifty feet above that level. The next begins at about twenty feet below high-water mark at Ludlow, Kentucky, opposite the western end of Cincinnati, and extends to probably ten feet above that line. The next extends to the base of the so-called silicious sandstone. The fourth includes this sandstone series, which, with its intercalated limestones, is probably rather over sixty feet thick. The fifth includes the beds from the silicious section to the Cumberland sandstone, which, totally interrupting the Cincinnati series, cannot be called a member of that group. These five sections of the Cincinnati Group are hardly to be called well determined divisions, inasmuch as their geographical extension has not yet been ascertained. They seem, however, to depend on features which should have a considerable horizontal extension. I shall therefore designate them as sections A, B, C, D, and E, of the Cincinnati Group, beginning with the lower division of the formation.

Looking closely at these beds, with a view to determining the history of their origin, we see in the section lettered A sufficient evidence that the deposition was made under circumstances which limited the amount of matter swept from the shores to pure mud. I have never been able to determine an arenaceous element in the rocks from this level. The fossil contents also seem to show that the conditions were generally those of deep water. The principal fossils are ~~trilobites~~, the exuviæ of which much abound at this level. It is not easy to see which was the principal lime-forming fossil; but I am doubtful if any of the recognized fossils could have furnished enough to make the cement of this argillaceous limestone. The general character of this part of the section shows us that it was accumulated slowly, so that each foot of thickness may well represent many centuries of time.

The next section, which we have termed B, gives us a succession of heavy beds of limestone, the principal fossils being the species of crinoids, which form the essentially characteristic fossils of this level. The same absence of arenaceous

material is noticeable here as in the beds below. But there is a bed wherein we have a considerable number of pebble-like masses of an argillaceous material lodged among the fossils in such a way as to convince me that they cannot well be accounted for except on the supposition that they are really pebbles worn from some neighboring shore. We have no reason to suppose that a stone formed of materials similar to the underlying rocks of this district would have furnished any arenaceous matter, so it is not an argument against the hypothesis of a neighboring shore to say that there is no noticeable amount of sandy matter in this level. This section must be regarded as one of the divisions in the Cincinnati Group, where the organic life was most abundantly developed. This development took place in a sea entirely free from currents, and continued without decided change through a period during which many new forms of life unknown to the lower beds were brought into this sea. I am much inclined, from the greater luxuriance of the life, the fewer tribolites, as well as the evidences before referred to, to believe this was a period of comparatively shallow water.

The next level, which is peculiarly that of *Trinucleus concentricus*, is ushered in by evidences of a return to deep water again. The fine clay, which closely resembles in its general character the mud brought up by deep sea soundings, comes again into predominance. The rich assemblage of life fades away for a time, and there are many feet of beds in these layers, showing an exceedingly slow accumulation of matter. The return of the life near the top of this series is gradual, and the assemblage different from that seen before. *Platystrophia* (*Orthis*) *lynx*, *Orthis testudinaria*, and *Plectambonites* (*Leptaena*) *sericea* come in here probably for the first time. All the forms are quite small, there being none of the exuberant life which is so marked a feature in section E.

The change to the level of the "silicious mudstone" of Dr. Owen is sudden, and cannot be ascribed to any other cause save the assemblage of conditions brought by shallow water and neighborhood to current-swept shores. Although these

alternations of sandstones, shales, and limestones occupy nearly a hundred feet at its thickest, we cannot regard it as representing a great duration of time. It may be accepted as a general truth, to which exceptions, if any occur, are rare, that sandstones are always more rapidly accumulated than limestones, and that, other things being equal, we may measure the rate of accumulation of any section by the amount of arenaceous matter it contains. The deep sea clays, derived, as they seem to be, from the decay of the free-swimming animals, must accumulate with extreme slowness. Though the rate of accumulation is unknown, we may safely suppose that an inch probably represents the accumulation of very many years. The instant that geological changes bring this region of sea floor into a position where the sandy deposits can reach it, then the accumulation goes on apace, and the rate of growth may be hundreds or thousands of times as rapid as it was during the deposition of the fine clay. It is probably to this rapid accumulation that we owe the barrenness of life so characteristic of most sandstone interruptions in the sequence of limestones. The moving sands smother the living forms of the sea precisely as the wind-driven sands of the land smother forests when they happen to invade them. The smaller, more delicate, and slow-growing forms are apparently the first to be extinguished by the new conditions. The larger brachiopods and other shell-covered animals are tolerably well guarded against this danger.

At certain points in this section there are beds which are, in some regards, like the fine clay of the lower series, but differing from it in being yellow or grey in place of blue, and in containing a distinct, rather coarse grit. They also differ in chemical composition. This mud may also be largely of organic origin, but it did not come as the gentle uniform shower which marks the earlier deposits, but seems to have accumulated rapidly. Many specimens of fossils are carried with it, after the fashion of recent shells in regions where there are great movements of mud from the action of the tides. Near the top of this section we have one strong evidence of the

action of currents in the quantities of shells packed together by this action. We can in a fashion measure the energy of their movement by the size of the transported fragments. None of the movements seem to have been able to stir the large specimens of *Platystrophia* (*Orthis*) *lynx;* but the shells of *Strophomena alternata* are often pushed along, turned on edge, and packed together just as I have seen the shells of the *Pectens*, along our Atlantic coast, affected by the tide currents. The shells of the little *Atrypa modesta* also show the same evidences of current action by being heaped together in sheltered nooks. Careful study will doubtless show the direction whence these currents came, but I have not yet been able to get evidence on this point. The beds which would exhibit this action are not valuable for quarry stones, and the fragments which, on the surface of the plowed fields, tell the general story as I have interpreted it, do not, from their detached nature, give the basis for ascertaining the direction of the currents.* The existence of sweeping currents may be regarded as a sufficient evidence, when taken in connection with the quantity of sand and mud, of the shallowness of the water and the neighborhood of a shore, where the detrital matter would be swept.

The next division of the section, that designated here as E, gives us at once evidence of the return to something like the earlier conditions. The clay element of the rocks is again blue and free from much grit. The evidences of currents are no longer to be traced. The organic life which, though favored by the currents, had been diminished by the overflow of sand and mud swept along by them, begins to give evidence of the most luxurious development. In this, the uppermost section of the group, the fossils which have been continued from below, as the *Strophomena alternata* and the *Platystrophia* (*Orthis*) *lynx*, are represented by larger varieties, while the new forms introduced are generally of much larger size than the average of similar forms below this level. The rock is principally a

*The extensive grading work now being done at Cincinnati would give sufficient opportunities for this desirable investigation. I beg leave to commend it to the many zealous and observant naturalists of that place.

limestone, composed, in the main, of the remains of the several species of brachiopods and of corals belonging to the several varieties of *Chætetes lycoperdon*. It is frequently interrupted by thin beds of blue clay, which is essentially the same as that which is found in the lower-lying beds. The large number of brachiopods found in this level give the soils derived from its rocks the peculiarly fertile character which is so prominent a characteristic of them. Certain brachiopods as is well known, generally contain a considerable quantity of phosphate of lime, so that the fertility of new soils may, in a general way, be determined by the extent to which these species abound.

The section we have designated as E has sufficient horizontal extension to make it worthy of a special name, and I venture to designate it by the name of the Kentucky River limestone, from the fact that it is found well developed on the waters of that stream, and has a thickness, varying in different sections, but which may be reasonably estimated at about one hundred and twenty-five feet. At only a few points along the border of the field have I been able to get any basis for estimation, owing to the fact that it is generally only a part of its original thickness that is left.

The passage into the sandstone which closes the series, here designated as the Cumberland sandstone, is quite sudden; a few feet very frequently accomplishing the whole change. I have noticed that the mud coating of the fossils adjacent to the top of the series is more common than at other points above the level of the silicous sandstone or section D. The extinction of life in the Cumberland sandstone is far more conspicuous than in the sand inundation of section D. In the last named section a large part of the organic forms in existence at its beginning continued on to its end; but in this sandstone I have yet to find the first distinctly recognizable fossils. Its greenish color, which is especially characteristic of the rock in its southward extension, along the Cumberland river in Cumberland and the adjoining counties, distinguishes it from every other extensive sandstone known

to me. The cause of this peculiar feature escapes analysis, but it is not impossible that it is due to phosphate of iron or some other similar substance; in which case it may owe its color to the organic life of the waters in which it was deposited. The considerable thickening, which takes place as we pass to the southward of the Ohio river, is a tolerably clear proof that the fine-grained sand, of which it is composed, was derived from some source of supply situated in that direction. It is likely that this was an extension of the high land which now forms the northeast corner of Alabama and the western part of Georgia. Many other regions of North America show us the existence at this time, of these conditions which set pebbles and sand afloat at the mercy of the currents of the sea. At this time, in New York, the Oneida conglomerate and Medina sandstone comes in the same general relation to the section of the Cincinnati Group, and may fairly be regarded as the equivalents of the Cumberland sandstone. As there are several of these lifeless sandstones in the section passed through between the base and summit of the Kentucky series of rocks, we will be compelled to give some special consideration to the question of their meaning; but inasmuch as the most extensive and instructive of these beds is found in the rocks which underlie the true coal measures, and come nearly on top of the carboniferous limestone, the question may best be discussed when we consider that part of the section.

Looking back over the numerous changes which occur in the rocks of the Cincinnati period, we are struck with the fact that they all indicate a tolerably continuous deposit of a fine clay, which may have taken place at a more rapid rate at one time than at another, but which never entirely ceased during the period. When organic life, especially molluscan and crinoidal forms, abounded, limestones were formed, more or less argillaceous, according to the relative rate of the two deposits. A rapid accumulation of the waste of the creatures living on the sea floor, giving limestones with little clay, from which there is a series of more and more clay until we have the

purest argillaceous beds. In these beds with the most clay there is always more or less lime, showing that organic life has had its part even in the most barren looking of the deposits. The deposits of sandstone seem all to have some trace of the clay in their composition, so it will be reasonably safe to say, that the deposition of clay was a continuous and tolerably equable action, the sand and lime coming in an irregular way from time to time, giving us argillaceous limestones or sandstones. The sandstones being deposited rapidly, contain proportionately little clay.

The theory of the inclusion and preservation of ancient sea waters in our Paleozoic stratified deposits appears to receive some confirmation from the history of these rocks. There can be no doubt that these beds were laid down in the ancient seas much as we find them at present, and that, whenever we penetrate below the general surface of the country, we find ourselves within rocks which show the existence of a considerable amount of just such materials as go to make up sea water. The abundant saline springs in this district of the Cincinnati Group is a matter not only of economic but of scientific importance. I cannot, however, unqualifiedly accept in this case the theory of the eminent chemist, Dr. T. Sterry Hunt, which is to the effect that these salt water springs are fed by the waters of the old seas in an unconcentrated state. The fact that springs such as those at Blue and Big Bone Licks have been flowing for a great space of time, reasonably to be estimated, as we shall see, at hundreds of thousands or even millions of years, is a strong point against this opinion. It is impossible to believe that these streams would not have completely drained all the region from which they take their water supply. If the mere inclosure of the sea water of ancient seas could furnish such a supply, this brine character should be common to the waters of all rocks where it had not been effaced by drainage. Other things being equal, the recent rocks should show it more clearly than the old, for there would have been less chance of their having been drained or worked out than in the more ancient deposits.

The ordinary rocks of the Kentucky series do not hold more than three per cent. of their mass of water when fully charged, so that in a region such as Big Bone Lick the whole of the beds above the springs, which may be averaged at two hundred and fifty feet deep, would only contain about seven feet of this imprisoned water. As these springs cannot be supposed to pour out less than two hundred cubic feet per diem, it is evident, on calculation, that a square mile of this section could only furnish enough water to supply one million days of flow, provided all the water of the section not in chemical combination was completely drained away. And it would require a district about twenty miles square to furnish the supply for one million of years. I am therefore compelled to believe that this region has been subjected to some action which has stored up the concentrated salts of the ancient seas. In the present state of our knowledge we know of no other way in which this could be accomplished except by fencing the region out from the direct sea, and allowing the process of evaporation to carry the concentration of the water to that point where the saline matters are, in part, thrown down on the bottom. This precipitation, it seems to me, need not necessarily have occurred in the beds where we at present find the saline matter. Let us suppose that in some overlying rock, which has since been worn away from this surface, a considerable thickness of sea salts had been deposited there, the action of well known forces would certainly tend to distribute the matter downwards to the underlying rocks, provided the structure was sufficiently open to permit the passage of water, or even the contact of its molecules, throughout the mass. I am inclined to think, however, that the now known salt belts, which exist below the top of the Cincinnati Group, can be explained by the fact that they occur in or about sandstones or other evidences of shoal water. These salt levels are probably the strongest evidence that is furnished to us of the upheaval of this region to the level of the water, on one or two occasions, during the formation of the Cincinnati Group.

The next level above the Cumberland sandstone brings us to the beds which apparently answer to the Niagara Group, so far as can be determined by the few fossils which they contain. This deposit is seen at points from the Ohio river southwardly to the Tennessee border.

It is evident that this section increases in depth as we pass to the southward, just as was the case with the underlying Cumberland sandstone at Mount Sterling; and to the northward, the great mass of the diminished section is cherty. As we go southward, the cherty structure is greatly diminished. Inasmuch as there is no break in continuity yet observed between the top of the Cumberland sandstone and the top of this so-called Niagara series, we may reasonably regard this mass as representing the whole of the series from the top of the Medina sandstone to the close of the Niagara period, as limited in New York. As yet the amount of work done on this formation within the State is so small that it will not do to make many general statements about it. It seems to show a long period of accumulation, during which silicious limestone and the overlying curious whitish shales were being slowly deposited, probably in a sea of great and steadily increasing depth. Immediately at the close of the Cumberland sandstone, which doubtless shows shoal water, this subsidence sat in. The flinty limestones are the first evidence of deepening water, limestones of this class being generally the product of deeper seas than the limestones destitute of this mixture. The finely laminated clays come next, and give what seems to me good evidence of slow, deep water deposition. This deepening seems to have culminated in the succeeding formation, as we shall see hereafter. In East Tennessee the beds are very much thicker than in Central Kentucky, and contain a large amount of coarse sediment, principally thin-bedded sandstones, and at the very top, including a true conglomerate, which, though possibly rather local, yet marks distinctly the extreme nearness of the shore.

The most remarkable feature in this formation is the presence at various points of extensive deposits of iron ore. At

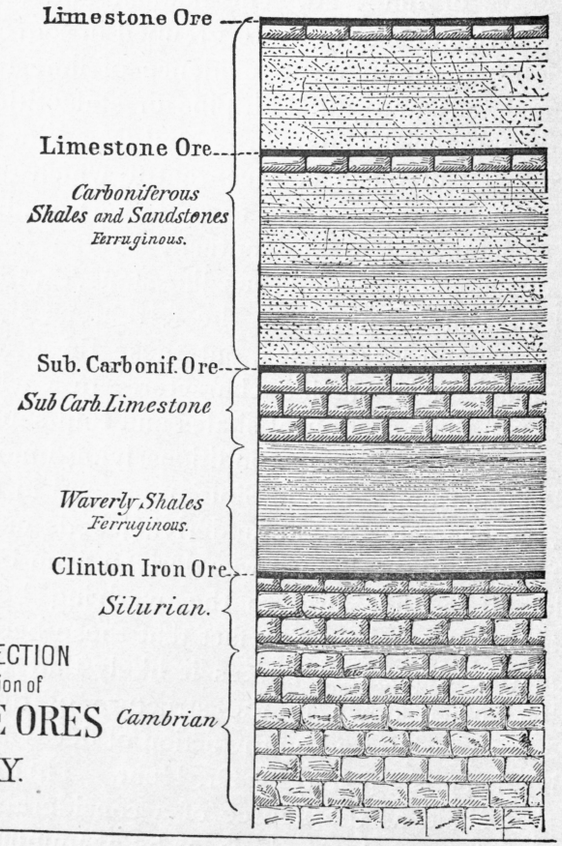
its upper limit this feature is by no means peculiar to Kentucky, but occurs at about the same level all the way from New York to Alabama. Not that the iron ore is found at every point, but there is probably not fifty miles along that great distance where it is not found in a noticeable development. Wherever this deposit occurs it is in the shape of a bed of fossils, which undoubtedly once constituted something like a limestone or a calcareous shale; the iron having, however, in most places, taken the place of the original material of the fossils so as completely to replace the lime. The exceedingly important question of the origin of iron beds of this general character receives some light from a consideration of these deposits, which, occurring about the level of the Clinton limestone in New York, have commonly gone by the name of the Clinton ores. It is evident from a study of the varied conditions under which the beds of this section were deposited, that if the ore was laid down at the time when the beds were formed, then it must have been deposited under the most diverse conditions imaginable. In New York it must have been deposited in a shallow sea, near the shore where limestone was forming; in Pennsylvania, under similar conditions; in East Tennessee, in a shore line where rapidly accumulating sandstones formed a prominent feature; in Kentucky, at the bottom of a deep sea, probably at a considerable distance from the land. It is evident that this view is not tenable. Following the safe rule of modern geology, and testing the operations which have gone on in the past by the actions of the earth at the present day, we may safely say, that a deposit of iron under such circumstances is impossible. There is no known way in which iron can be laid down in the form of marine beds in the deep sea. Some small quantity of iron is contained in many sea-weeds, and, doubtlessly, where they continually decay on the same spot (as has been suggested by Pumpelly*), there may be an accumulation of iron, probably in the shape of a shale containing some of that metal distributed through its mass. But these thick accumu-

*See Reports of this Survey, new series, vol. II, page 318 *et seq.*

lations, where in some cases more than sixty per cent. of the mass is iron oxide, cannot be thus accounted for, and the only way to explain them is by supposing that, in some fashion, we have had a concentration into one plane of a quantity of ferruginous matter which had originally been deposited either above or below that level. As the methods of this action are not only of great scientific but of exceeding economic importance, I have given the subject a good deal of attention in the field. The various ferriferous levels of Kentucky afford us a considerable variety of conditions, which may be grouped, in a general way, into three classes, viz: 1st. The limestone ores, where the conditions show us that the iron has replaced carbonate of lime; 2d. The nodular and black kidney ores, where carbonates of iron are grouped in segregated masses on levels where there is no evidence of limestone having been accumulated; and 3d. The pipe or stalactitic ores, which are clearly superficial beds worked out from older deposits.

The first of these classes, that to which the so-called Clinton (which I prefer to call the Silurian) ore belongs, is represented in the State of Kentucky by the bed formed on the top of the Sub-carboniferous limestone, and by the bed in the coal measures known as the ferriferous limestone. There are other and local cases, but these three are the only wide extending beds of this character. In each of these cases there is a thick section of shales and thin sandstones presumably deposited in marine conditions, lying immediately over the beds in question. In the Silurian ore and in the Carboniferous ore, the character of the underlying beds makes the supposition that the iron deposit was derived from below quite impossible. It is, therefore, to the overlying beds that we must look for the supply. The fact that these beds are the product of marine deposition makes it likely that the iron was originally carried down in the structure of the depositing seaweed, or precipitated by the action of decaying organic matter, as has been suggested by Dr. Hunt. Then we may well look to that shale as the source of a considerable supply of iron. It is easily seen by analysis, or by examining the springs that

originate within the Ohio shale, that there is a considerable store of iron in that mass. The same evidence may be had in the case of the marine shale section, which, over a large part of the State, lies immediately on top of the Sub-carboniferous limestone. As all rock masses, save, possibly, at depths below the range of man's observation, are injected with water, it is not unreasonable to suppose that heavy matter, such as the oxides of iron, may be slowly and steadily working downwards through the menstruum of water. It is evident that this action must be going on whenever in any region the drainage level has cut down so as to drain the beds which happen to underlie the shale in question.



DIAGRAMATIC SECTION
showing position of
LIMESTONE ORES
in
KENTUCKY.

In the accompanying figure, it will easily be seen that in the case of the part of the section above the level of the drainage, the downward working of the contained iron is a matter of necessity; and if we acknowledge that the lime carbonate of the limestone has any special power of arresting the moving iron, it follows of necessity that a deposit will be made at the point of junction of the lime and the overlying shale in sandstone, from which the iron is working downwards. It is, however, not so clear that the iron contained within the shale which lies beyond the drainage, is under similar conditions of downward working. As far as the movement of the iron towards the limestone is the result of the actual current in the water, brought about by the drainage outflow, of course it would be wanting at the points represented below the drainage; but the downward working may be due not alone or in any great part to the drainage movement of the water, but rather to the *osmose* movement, which leads to the equalization of matter through the whole of any fluid mass in which it is contained. I am not aware of any experiments to show the distance to which this movement may extend, but it seems a necessary consequence of the law of *osmose* action that the process of equalization should go on through the whole of the section where the particles of water run in contact, the only question as to its efficiency being the time required to accomplish the given result. This is by no means an abstract question, but one which most intimately connects itself with the future interests of the country. Long before the fuel resources of this country can begin to be exhausted, the iron ores of the superficial regions, and those known to be rich at greater depths, will have been exhausted The problem is the same for the world at large—the resources of the one absolutely necessary metal, the material without which we cannot imagine civilization to keep its place, are not nearly as satisfactory as the resources of heat and light, those other factors of civilization.

There seems a great chance that, long before fuel is exhausted, the available iron of the world will be wasted into

the sea or the soil. If, however, we can prove that these Silurian and other limestone ores are continued beneath the drainage of the districts where the beds which have formed and contain them are found, we enormously increase the possible iron mining area. The rich iron district of East Tennessee may then be continued beneath the overlying rocks, and occupy a large part of the area covered by the Carboniferous and other superior beds. If we could prove that only one tenth of the buried rocks of this level and of the Sub-carboniferous limestone are covered with workable iron ores, we would thereby probably add more iron to the known store of North America than is included in all the deposits which have as yet entered into our considerations. The only way in which this matter can be definitely decided is by borings made quite through these basins at a number of points where the rocks are clearly below the drainage level.* To determine the existence or non-existence of this iron ore beneath the drainage, borings should be made at selected points along the Cumberland Mountains. The great north and south extension of the ore on that line would make it nearly certain that it would be found beneath the drainage, in case its formation was not due to the drainage action itself, which I cannot easily believe. I should consider the failure to find the deposit at a very few borings made along this line, and not necessarily more than three to five hundred feet deep, as sufficient to determine the matter. I do not propose at this time to undertake to discuss the general question of the genesis of iron ores; so with this reference to a possible explanation of this special deposit I shall pass again to the question of the character and history of the rocks in which it is found.

*Nothing better illustrates the importance of a continued scientific observation of any State than the fact that in this State, during the various borings for salt and oil made in the last half century, abundant opportunities have occurred for the most complete determination of this point; but they have been entirely lost through the want of some system of State inspection of its mineral districts. To repeat these borings on anything like the same extended scale would, I estimate, cost not far from one million dollars. I have no doubt that within a century this sort of exploration will be repeated with equal cost, perhaps not in search of the same things, but with some other quest which could be fully answered by an examination of the borings of these hills, had they been carefully collected and preserved. One per cent. on this capital would maintain a watch on all the underground operations of the State, and thus continue the work of a geological survey after all the surface indications had been completely investigated.

This so-called Clinton iron bed may not be unusually found at the top of the Silurian section. At many points it seems to be nearly, if not entirely, absent. Far too little study has yet been given to the extension of this ore deposit to make it certain just how generally it is to be found. Owing to the softness of the overlying shales, the top of the series and its contained beds are not often clearly seen. It will be our especial object, in the future work of the Survey, to get all possible information on this point. At some points the passage into the black shale shows several alternations of silicious beds with the shale. Generally, however, it is pretty abrupt, and we pass quite at once into the Ohio black shale. This remarkable formation, by far the most inexplicable of all the beds of this country or in Europe, is more nearly limited to the Ohio Valley than any other of the formations which have as yet been found within its basin. I therefore propose for it the name of the Ohio shale. I am aware that it has already been termed the Huron shale or the Huron beds; but this name is not satisfactory, inasmuch as it is likely to be confused with the Huronian formation, when the name of this great lake was first connected with a system of rocks. The name would be, moreover, quite out of place applied to beds which have very little connection with the region of that lake. Probably more than five eighths of the Ohio basin lie over this formation; over some tens of thousands of square miles it constitutes a large part of the surface rock. On these accounts I have deemed it best to give the name of the Ohio shale to this formation.*

With slight local differences, from point to point, this formation consists of a tolerably uniform mass of thin-layered bituminous, petroleum-bearing shale, accumulated in a very uniform succession to the depth of one hundred feet or more. The inorganic matter is a fine mud, such as we have deemed elsewhere to afford evidence of deep sea at the time of its deposition. The organic matter is so far changed that it is not easy

*I have concluded, in the naming of local beds, to follow the plan of naming them after the river valley where they are most abundantly developed.

to determine whence it came. In Kentucky, along the Ohio, near Vanceburg, in the workings made a number of years ago, when the shale was distilled for coal oil and paraffine, there were a number of jaws of fishes and other parts of the same animals found imbedded in the shale in a disorganized state, as if the whole animal had not been buried at the same place. At various points over the southward extension of this formation I have found similar remains, in rare cases scattered throughout the whole section. The only other fossils found have been remains of two or three species of brachiopods, allied to the Lingulas, and which seem to have been very small members of the group. None of these fossils give any clear indications as to the fresh or salt water character of this deposit. The fishes at no time in the earth's history have left evidences which would make it certain in which conditions their lives were led, and the brachiopods of the group of Lingulas are, as I shall hereafter endeavor to show, by no means certain indications on this point. Considering the very great extent of this formation, it is not unreasonable to suppose that the deposition must have taken place on the sea bed, and the absence of all coarse detritus, such as coarse sand or pebbles, the general evenness of the mass, and the want of all the fossils which generally characterize the shore line, is tolerably conclusive evidence that the beds were formed in deep sea far from the land.

The important fact that this formation, unlike the Cincinnati Group, the Niagara section, the Sub-carboniferous lime, and the Conglomerate, does not materially thicken as we approach the Unaka Mountains, points to the conclusion that it derived no waste from that section. Its thinning as we go towards the Gulf of Mexico, while the Cumberland sandstone, the Conglomerate, and the Sub-carboniferous limestone all thicken that way, points likewise to the conclusion that the land area, whence the mechanical element in the composition of this shale was derived, lay to the northward of the Ohio; the region to the southward being pretty generally submerged at the time of its formation. The extreme ease with which

shale is eroded makes it doubtful how wide was its original extension. The absence in its structure of distinct marks of nearness to shore seems to me convincing that we have nowhere found its shore line. If it was followed, as we shall see reason to suppose hereafter, by a sudden and tolerably complete return to shoal water over a large part of the area occupied by its deep sea, then the marginal parts of the deposit, being left unprotected by subsequent accumulations, would have quickly faded away before the erosive forces, as it now disappears whenever not sheltered by harder overlying beds.

The large amount of petroleum which is always contained in this set of beds may well excite our astonishment. Something of the facts are given in the economic section of this report. It remains to look a little to the theory of its production. It is evident, in the first place, that this matter must have been formed where we now find it, for it could not have been derived from the deposits which lie above or below its level. The series of the Cincinnati Group and the Silurian, properly so-called, have, throughout this section at least, no considerable amount of such matter in their structure, nor does analysis teach us that their organic contents could ever have yielded a great store of carbonaceous matter. The overlying rocks are arenaceous, and were doubtless made in seas where the development of organic life was relatively very small. Within the Ohio shale itself the beds furnish us little else save fish remains; and I was, at one time, disposed to believe that to these animals we must look for an explanation of this organic matter. It seems to me now, however, that the suggestion of Dr. Newberry is more likely to furnish the true solution. His hypothesis is, that the region was the seat of a great sea-weed deposit, being on the floor of a sort of Sargassum or Sargasso sea, such as now occupies the central part of the North Atlantic. The only difficulty is to see how any known form of sea-weed could have formed such a mass without leaving some distinct remains of its structure. The present forms are those which would be likely to make fre-

quent fossils in mud of this consistence. Some vague markings are to be found there, but nothing like the distinct marks which, in earlier and later formations, as in the so-called "Caudi Galli," of the New York series, and of the Waverly sandstone, mark the presence of these organic forms. It is not unlikely that the deposit is the result of long-continued slow deposition, wherein sea-weeds, fishes, and possibly many invertebrate animals, contributed to the waste. The presence of many large and vigorous fishes goes to show that they must have had an abundant invertebrate life for their support. The absence of the fossils of the softer animals may be explained by the want of sufficiently rapid accumulation to insure their burial.

The conditions under which deposits of organic matter form hydro-carbons are not well understood. I am inclined to think that we cannot reasonably suppose that the change took place long after the deposition of the beds which form the shale. The conditions of the beds that lie below the black shale, in the Cincinnati Group, or in the Niagara section, show that there has been no great invasion of heat since the beds were deposited. Clays, which change greatly under a heat of one thousand degrees of Fahrenheit, are apparently exactly as they were left by the sea, and beds retain their marine salts just as when they were deposited. Any great access of temperature in this deposit of the Ohio shale would have been attended by an almost equal rise of temperature in the coal beds which lie within a few hundred feet above; but these coal beds are free from any evidences of distillation or other consequences of heat. We have already seen reasons for supposing an erosion of some three or four thousand feet of strata from this section; if we could reimpose this section, we should probably bring up the temperature of these rocks, by the rise in the isogeothermals, or lines of equal internal heat, about sixty degrees, granting that the rate of increase in temperature has grown less after the rate indicated in the calculations of Sir William Thompson.

We are not able to suppose that the accumulation of strata could have elevated the temperature above the point of boil-

ing water. The hypothesis which may be formed to account for the formation of this coal oil must take into consideration the impossibility of its generation at another point and its removal to this set of beds, and the impossibility of supposing that it has been, in any way, the result of high temperatures.

I have already referred to the large results obtained from the distillation of this shale. (See biennial report in this volume.) It should be noticed that these determinations are based not on the substance from points where it has been excluded from weathering, but on material taken from points above the drainage and near bluff banks, where it was exposed to thousands of years of slow decay and washing. Wherever I have been able to hear of borings below the level of the drainage, the mass has been found completely saturated with the oil. At many points the progressive leaching of the mass is readily determined. The outside surface, and within for several feet, may be quite deprived of its hydrocarbons, and as we go from this face there seems to be a progressive increase in the quantity of those matters. On all these accounts I feel justified in saying, that the normal state of the deposit is that of complete saturation with coal oil.

The equivalency of this shale with the deposits in New York has been a matter of much discussion. The section in East Tennessee, when compared with those of Kentucky and New York, has satisfied me that the Ohio shale includes everything from the top of the Oriskany sandstone to the top of the Chemung.*

In East Tennessee the Silurian and Devonian sections are still faintly recognizable. On top of the evident Clinton and Niagara fossils, some beds are found containing *Leptocœlia* of a species closely allied to, if not identical with, the characteristic species from the Oriskany sandstone. The other organic species of this group ally themselves with those from the Oriskany sandstone in many important regards. Above these beds come a set of barren beds, thirty or more feet in thick-

*This question I hope to discuss in the Memoirs of the Survey, for which purpose data concerning the Ohio shale are now being collected. A brief and rather unsupported statement is all that can be made here.

ness, with a considerable conglomerate bed, which, being deposited in patches, is strong evidence of shore or shallow water conditions. In Central Kentucky this Oriskany sandstone is merged in the Niagara series so completely that I have not been able to separate it or to find its characteristic fossils. This evidence satisfies me pretty well that this black shale does not include the beds contemporaneous with the Oriskany sandstone. In East Tennessee the Ohio shale comes immediately on top of the beds which I believe to represent the Oriskany sandstone. In Kentucky it is found immediately on top of beds which, certainly, are not higher than the Oriskany. In both these cases the surfaces are entirely free from any symptom of erosion. Therefore, allowing that these beds have not been eroded, it follows, of necessity, that the black shale in this section, as far as may be judged from this evidence, includes all that follows the Oriskany sandstone up to some point yet to be determined.*

Although there are some argillaceous and slightly calcareous bands in the black shale and one or two silicious layers, I am unable to make any satisfactory decisions as to its origin. I believe there is no section in our beds representing anything like the amount of time which it requires, and having anything like the uniformity of structure possessed by this Ohio shale. When, therefore, we find evidence that the beds which immediately overlie the black shales belong to a section later than the last of the lower rocks in New York, that, in a word, we have passed in it through the whole Hamilton period, through the whole Chemung period, and possibly through a still later time represented by the Catskill Group, we are driven to suppose that this was a region which had no share in the disturbances which took place in New York. The easiest way to account for this uniformity of conditions is to suppose that it

*I am disposed to insist on this method of determining equivalency notwithstanding its serious consequences. It is always to be remembered, that as long as a region is beneath the sea it is always receiving some sediment, however little; so if at any point we should find Cincinnati Group fossils, and then a few feet of shales followed by Tertiary beds, the whole well exhibited, with no evidence of a break by erosion, we would be logically compelled to assume that this thin section represented all the vast period of the earth's record between these two horizons.

was buried deep in the sea when the changes of level took place, which may have brought great modifications at the shore. Whenever the Atlantic coasts rise and fall suddenly, by say five hundred or a thousand feet, prodigious changes are necessarily brought about in the beds which are forming, new fossils are brought to the area, and other kinds of sediment laid down. But in the deep sea these changes probably bring no break in the uniform succession of events. Its Sargassum sea will keep about the same place, and it certainly is a rare chance that anything occurs to mark the change of level in beds just beneath its surface.*

I am inclined to accept Dr. Newberry's conclusion concerning the equivalency of the beds, termed by him Waverly, which immediately follow the black shale. He gives them a place at the base of the Sub-carboniferous rocks, and their fossils certainly bear out this classification. In Kentucky this section varies from about six hundred feet thick, along the Ohio, to rather less than half that amount, where they are disclosed along the Cumberland river in Clinton county, and to about two hundred feet at Cumberland Gap. Wherever found within Kentucky, its history is evidently that of a rather shallow water formation, deposited at a period when the transportation was by gentle currents, without the violence which seems to have affected the ocean movements in this region at a later time. As we go southwards this formation becomes less distinctly sandstone. The clay element increases, though this is generally silicious, the formation giving little trace of the carbonaceous character common to the Ohio shale and to the carboniferous shaly beds, save at one point near the Ohio river. In East Tennessee, twelve miles north of Cumberland Gap, it is still very sandy, the beds being quite thick though rather incoherent. It abounds there with the Spirophyton or "Caudi Galli," which is abundant along the Ohio river. At Cumberland Gap we begin to get many beds of dense silex or chert, but the larger part of the mass is still a very silicious,

*See Vol. II, new series, of these Reports, p. 327, for some matter from the pen of Professor Pumpelly, which has an important bearing on the question.

indurated clay shale. Forty miles further south, near Jacksboro, Tennessee, the amount of cherty matter is greatly increased, so that the mass well deserves the name of "Silicious Group," given it by Professor Safford in his Geology of Tennessee. This rapid change is apparently attended by a certain shrinkage in the thickness of the formation.*

The same change, though carried to a less extent, occurs along the Clinton county section, where the presence of silicious matter is also a conspicuous feature in this formation. The greenish color in the beds of this age is a striking feature at many points, and reminds us of the tint observable in the Cumberland sandstone. The great amount of these arenaceous deposits makes it pretty certain that these beds of the Waverly series were deposited with great rapidity. They probably do not represent more than a very small fraction of the time represented by the beds of the black shale. Sand deposits are necessarily made with rapidity. They demand for their formation the energetic action of the sea upon a great extent of land. It is on this account that they are peculiarly the product of periods of rapid change of level. Along the Atlantic coast of the United States we see the result of these changes in a striking manner. There has been a general rise of the whole of that coast since the middle tertiary; and the retreating sea has carried back with it a great quantity of sand. From each of its great invasions the sea bears back a rich booty in the sands worn from its receding shores. During the period when the sea is gaining on the land the forming sands do not work seaward. Their limit is made by the depth at which the currents cease to have a sweeping power, and with a sinking shore, these are continually working in towards the centre of the land. When the sea goes back it is with full hands, and the sand-beds work out over the sea bottom with great

*I am aware that I differ from the able geologist above mentioned in my opinion as to the age of these cherty beds of the region from Cumberland Gap westward. I shall endeavor to discuss this question more closely hereafter; but for the present I can only express my respectful dissent from the opinions of my learned friend on this matter.

rapidity. The currents, then, have all that they can carry away.

Along the shore of Massachusetts and Connecticut the sands washed from the newly risen shore, and scattered far and wide over the sea, make a deep bed, reaching on the average nearly two hundred miles from the land, and having a depth, probably, averaging over fifty feet. All this vast mass is the product of a short time of carriage and deposit—so short that it is difficult to exaggerate its brevity in a geological sense.

This interesting question of the action of a retreating sea cannot be discussed here, but I trust enough has been indicated to show that there are reasons for believing sandstone series like the Waverly to be evidences of a general uplifting of the region where they were depositing, and a consequent sweeping of a long forming store of sand out into the sea. The question may naturally arise, what became of the coarser products of this erosion—where are the gravels and boulders which were encountered by the ancient seas? The evidence to give the answer is not wanting on our own shores: these coarser materials are either ground up on the shores, as the seas move over the land, or are to a great extent left behind in the movement, to be in time worn again and again, until they are finally quite reduced to the size when they can be carried by ocean currents.

Although the Waverly period seems to mark the steady uplift of this part of the continent, it is not certain that the sea bottom was bared over any great area at its close. Along the Ohio river there is some evidence of land, perhaps, to be found in the fire-clays occurring near its top. The idea that these beds are the exhausted soils of old forests has much to commend it. There is no other simple way of accounting for the formation of such deposits. If forests ever flourished in this region, subsequent waste has destroyed all trace of their existence. A careful study of these Waverly beds is yet to be made, and several years' work will be necessary to their full elucidation. These are only a few general conclusions of

value, which may be stated with some confidence. The absence of all pebble deposits is tolerably safe evidence that the shore was not extended across this State during the upheaval of the Waverly period. When this sand was formed there must have been enormous stores of gravel and boulders, and some part of this matter must have worked along the shore, if they were ever near here. The absence of such materials is presumptive proof of the distance of the shore of the main land.

At the close of the Waverly period this unstable region seems to have begun once again to subside; and with this subsidence comes an utter change in the physical and vital conditions of the sea. The complete interruption of the movement of sands is the first evidence of this change. With it comes the rapid development of great quantities of marine life, differing from, though closely allied to, the life in the beds below. The organic life showed its vigor in the many species of crinoids and brachiopods of large size. With the change this life rapidly developed most of the forms, gaining considerably in size and vigor of growth.

The enormous development of organic life of relatively high forms, and the rapid specific change of that life, serves to show us that the Sub-carboniferous limestone was not formed in a very deep sea; at the same time the far-reaching character of the deposit and its great thickness negatives the idea that it could have been formed in very shallow water. As we trace it to its end over the Ohio line, it has been supposed that it had its shore there. I have failed to find good evidence of this, however, and am disposed to attribute something of its absence to the wear that came after the final uplift, when the Carboniferous limestone became the basis on which the coal measures or their lower member, the conglomerate, was deposited.

In a general way this Sub-carboniferous limestone may be said to extend from the Ohio river westwardly, or rather northwestwardly, to the Rocky Mountains, where its thickness is very great, and southwardly to Alabama, and to have its east-

ern border against the ancient axis of the Appalachian chain. Except the rocks of the Cincinnati Group, it is the most extensive series of limestone known in our American section; indeed, at this time, throughout the world, there seems to have been a period of limestone production unequaled in its area and activity in all the earth's history. Not only in this country, but in Europe as well, a period of extraordinary limestone accumulation was begun at this time. This singularly active accumulation of limestone is doubtless to be, in good part, attributed to the existence of species capable of rapidly depositing limestone from the waters of the sea. Along with this, probably, went that gentle subsidence of the sea floor which is calculated to prevent the coarser inorganic waste of the land from invading the regions of the sea when deposition of an organic kind is going on. I am much inclined to think, however, that there was at least one other cause, which contributed to the formation of this great limestone deposit. The simultaneous formation over wide areas of such great deposits, formed under circumstances which afford tolerably good evidence that they were rapidly accumulated, leads me to suspect that there must be periods in the history of the sea peculiarly well fitted for the life of limestone-secreting forms. If, as I am inclined to believe, the amount of surface varies considerably in different geological periods, then it may well follow that the amount of calcareous matter in the sea, which is derived from the waste of the land by rain-fall, may vary considerably.

Taking the common estimates of rain-fall, and the usually reckoned depths of the sea, it would require about ten thousand years for the whole of the water of the sea to fall upon the land. This is really a rapid rate of movement in a geological sense; and in case anything happened to extinguish certain races fitted to recover this lime and related matters from the sea, there might be a considerable gain in these materials until some other form of life, fitted to discharge this matter, came upon the scene. We do not know in any other period an occasion when the discharge of carbonate of lime

from the sea was so rapid and long-continued as in this formation. That the formation of a large part of the limestone was very rapid is proven by the frequent great size of the organic masses which compose it.

In the case of reef-building corals, which seem to be the only members of the group capable of making extensive deposits of limestone, their development seems limited to the localities where they can be exposed to a sweeping current; in such positions the corals may occupy a region not over a few miles wide and generally only a few hundred rods in transverse extent. It would seem that, in passing over this distance, the water becomes so far impoverished that it can no longer sustain a vigorous growth of corals.*

In the case of the crinoid-covered sea floor the growth was not limited in any such fashion, but spread far and wide over an area of certainly hundreds of thousands of square miles, in all of which there is only the least trace of matter of an argillaceous or arenaceous character. I doubt if there is anywhere within the present seas, away from the coral reefs, any such great accumulations of limestone going on as this affords us, or if our present seas could supply the needed conditions in the way of calcareous matter.

The rapid growth of these beds is also, in a measure, shown by the considerable thickness of the several layers. In no other of our unaltered limestones do we find thicker beds. This is in part, certainly, owing, as I have already suggested, to the fact that the animals which formed the large part of this limestone grew, and to a considerable extent decayed, in an upright position. I am inclined to think that, if we could restore the old crinoid groves to the sea floor, and study the conditions, we should find them much as follows: the crinoid stems, thickly dotted over the sand bottom, where the decaying stems and branches, and the numerous molluscs, made a bed of already hardened limestone; those still living, would rise from two to four feet above the surface, and spread their

*This point should be determined by careful examination of the quantity of different substances contained in the water before and after it had passed across the reef.

arms some half a foot when expanded; the dead crinoids would quickly drop their heavy heads, but their stems would keep standing for some time, and were often half buried by the rapid growth of waste before decay brought them down to ruin. The molluscs, the corals, and other minor elements of the life, do little more than fill in the interstices.

Many of the beds accumulated on these old sea floors are clearly the product of other conditions. The very fine dolomitic limestones of Kentucky seem to have been made by an impalpable mud, in which few organic forms have ever been buried in a fossil state. I am not satisfied as to the history of these masses, but I am inclined to think that they mark a part of the time when the sea floor was depressed to a great depth —so deep as to exclude these forms of life, and bringing the sort of conditions now found in the deep sea region of the Atlantic.

The variations of thickness in this deposit in Kentucky are considerable. Passing to the southward, the thickness is tolerably proportionate to the distance from the Ohio river, though in the region below Louisville it attains a considerable depth. Its thickness at Cumberland Gap is about 450 feet. At the Mammoth Cave about three hundred feet are seen, and a boring for oil is said to have shown five hundred feet, and the boring stopped in this rock. In Northern Tennessee it is said to obtain the thickness of 900 feet.

It is quite natural that a limestone should gain in thickness towards the southward. It is more than probable that the temperature conditions, as well as the influence of currents in bringing supplies of fresh sea water, which we know to be most efficient means of aiding the growth of all marine invertebrates, were more effective the further south we go. To this cause I attribute also the gain in thickness of the Cincinnati Group, which passes from about seven hundred feet, on the Ohio river, to fifteen hundred feet in the region about Cumberland Gap.

So far as my observations go, the Sub-carboniferous limestone is divided in Kentucky into but two distinct members.

The lower or St. Louis is the massive and especially cavernous element. The upper or Chester begins to show a change from the conditions which brought about perfect freedom from arenaceous and argillaceous matter, and has its most important physical character given it by the return of the alternating sandstones and shales which form such a sure mark of the approaching shore. The Chester Group may be regarded as beginning with the first of the sandstones and ending where the limestone ceases.

There is no trace in Kentucky of the Carboniferous shore line, at least until we come to the later stages of the Chester. In the northwest and west there is reason to believe that these rocks were deposited nearer a shore; this is shown there by their less continuity and the greater predominance of the arenaceous element in their composition. To the south of Kentucky, at least about Cumberland Gap, this arenaceous element in the Chester becomes less conspicuous than it is even in the Mammoth Cave district; hence, I conclude that, as the first named region was more remote from the Laurentian shore, it may be that there was another shore line in the North Alabama section; but this last named district I have not examined in person. The immense and long-continued erosion of the period immediately following the Sub-carboniferous limestone, the results of which we see in the conglomerate or the millstone grit, probably wore away all the shore line deposits of this period, as well as the exposed shores of many of the older formations. Before the limestone-making creatures had been entirely driven out of this sea, there is abundant evidence that the carboniferous vegetation was already occupying the neighboring land, and ready to occupy the sea floor as fast as it was bared by the raising of the land.

In the upper Chester there are one or two beds of coal which sometimes attain to about a foot in thickness, and are found over the western coal field at almost every point where the limestone is exposed. In the eastern field this sub-carboniferous coal seems to be quite wanting. In the western

coal field, the transition from the limestone appears to have been much more slowly completed than in the eastern section, there being, in the Edmonson coal district, three or four distinct though thin beds of marine limestone within one hundred feet above the lowest or Chester coal, each marking a return of the sea over the land in the successive alternations of movement. Some trace of this alternation, though in a far less degree, is seen in the coal measures of Northeastern Kentucky. About Cumberland Gap, however, the limestones show no such return to marine conditions. When the limestone-building ceases, which it does pretty abruptly, it does not reappear in the subsequent two thousand feet of strata. I am inclined to attribute this, in part at least, to the far more considerable amount of detritus, which accumulated at the last named region, where the conglomerate is much thicker than it is in the Edmonson district, or in the northeastern part of Kentucky. This section, probably, remained in rather deep water long after the other regions mentioned had been brought to near the sea level. When this process of uplifting had ended the Sub-carboniferous period, by extinguishing the life which made that time so conspicuous, there seems to have been a time of comparative steadiness, during which the land retained its position with reference to the sea. Although local variations in the deposits make it tolerably difficult to make general assertions concerning the beds that succeed the Sub-carboniferous limestone, it is doubtless usually true that the Western Kentucky section gives us generally sandstones more or less dense, and but little shale. The sandstones and the shales seem to be fresh or brackish water deposits. In Eastern Kentucky, however, the amount of shales is relatively much greater than in Western Kentucky. Here, too, these shales were apparently formed in fresh water, and the conditions were sufficiently favorable for the formation of two or three beds of coal, within about one hundred feet from the top of the limestone. These beds of coal are about the most persistent and trustworthy of all the beds known to me, in Kentucky. These coal beds show very dis-

tinctly the uniformity of the conditions—the absence of all violence of a general as well as of a local character. At Cumberland Gap, those shales that lie just above the limestone, contain no coal or other signs of plant life, and are very sandy, being in places scarcely more than soft sandstones.

In these conditions of tolerable uniformity the first stage of the Carboniferous period was passed. As this period is set apart by its physical and vital conditions from anything that came before or afterwards, it deserves a special designation. I shall, therefore, in order to indicate my sense of its distinctness as a period in the history of the Ohio basin, as well as to avoid periphrasis, give it the name of the Kentucky shale. This name is especially fit, inasmuch as in the region about the head waters of the Kentucky river, we have the best exemplification of the Sub-conglomerate coal series which has yet been examined. These geographical names have some objectionable features; and when the identity of time and identity of conditions in two regions can be established, it is doubtless proper to retain one name for the two formations; but in all cases when the identity of time is questionable, or when the conditions were entirely different, I think a local name warrantable and desirable.*

In point of fact we know little about the exact correspondence in age of formations; so the less we do in the way of question-begging in the use of our terms the better. Like the other local names which we have adopted for our Kentucky rocks, it asserts a place of occurrence and something of the physical character of the bed, leaving the question of its precise horizontal equivalence to be determined hereafter.

It is quite evident that the exposure of the land was long continued, and that the area above the water level, in Western Kentucky at least, was considerable. On the lower waters

* It should be noticed that there are two elements to be denoted by a name such as Bath Oölite—the time when it was formed, with relation to the general history of the world, and the physical conditions existing at that place at the time when it was laid down. If we find at another point a series of volcanic deposits, a deep sea shale or recent plant beds, which can be identified in age, with the above named formation, it would not be reasonable to give them the definite name of Bath Oölite, or even Bathonien, in the generalized nomenclature of D'Orbigny.

of Nolin river, we have distinct evidence of the excavation of a large river basin in the rocks of this Kentucky period, after some of the coals were formed. Into this basin the moving pebbles of the Conglomerate or Millstone Grit period were poured, filling it up to a depth of two hundred feet or more. This section compels us to suppose that, after the formation of the Kentucky shales, there was a period of degradation, when running water cut down river beds as deep as those which now traverse the country.

There have been so few openings made into the rocks of this age in the way of mines, that we are not able to say whether this sort of erosion is common or not; but this is the only case that has been observed. The sectional area of the excavation is about as great as we could expect in the case of a stream of the size of the neighboring Green river, which, as is well known, drains a considerable area. The course of flow of the stream is not clearly marked, but the excavation has its axis in a northeast and southwest direction. There is enough known of the structure of the rocks of this period to make it sure that their surface was not exposed to any very destructive denudation at its close.

After about one hundred feet of coal-bearing beds had been laid down, there came a great change over all the physical and organic conditions—a change on many accounts the most inexplicable of any that are indicated in the whole series of rocks. We shall soon have to consider the nature and cause of this change; but it should be remarked, before alluding thereto, that this period, which we have called the Kentucky period, was, so far as our knowledge goes, peculiar to the Ohio Valley. In other regions the Millstone Grit, or the Conglomerate, comes immediately after the Carboniferous Limestone. In this region, the Carboniferous Limestone seems to have been brought to the water's edge sooner than at other points, and thus time was secured for the formation of the Kentucky shale. I am inclined to prefer this explanation to the hypothesis that the conglomerate-forming forces did not get into action at this point until long after they had begun to operate

at other points, though this last hypothesis may turn out to be true. It seems to me probable that a set of causes, competent to bring about such an extreme revolution, would have acted over the whole region at the same time; or, at least, would have advanced with too much rapidity to leave time for the formation of these shales. It seems to me, therefore, that these beds are, in fact, Sub-carboniferous, answering to the later stages of the limestone period in other regions. There is, however, no sufficient evidence of this; and it seems to me, therefore, best to denote the doubt by a geographical name, which does not prejudge the question.

The passage from the Kentucky shales to the period of the Millstone Grit was apparently attended by a slight and exceedingly uniform subsidence throughout all the Carboniferous region known to us. This down-sinking was not accompanied by a return of the organic life which usually comes with the returning sea. A vast mass of sand and gravel, urged by strong currents, swept over this region; no marine life whatever was developed in it, and faint traces of land life have been found wherever it occurs. We find it by no means easy to explain this period, with its inundation of detrital materials, by anything in the existing conditions of the earth; but in the events of the glacial period, which has just passed away, something of similarity may be discerned. We may from that period construct a hypothesis which will in the main explain the conditions of the Millstone Grit time.

During a long series of ages, in which the Sub-carboniferous Limestone and the Kentucky shale were depositing, the surface of the neighboring land to the north and east was probably undergoing that process of slow decay which clearly goes on wherever the land is for a long time exposed to atmospheric action. In a few million years to come, provided the region is not ice or sea-swept, the great primordial region to the north will have its rocks decayed to a great depth, just as they are now decayed in the Unaka section of the Appalachian system, as has been described by Sir Charles Lyell, and later by Dr. T. Sterry Hunt. The granites, syenites, mica

schists, and other allied rocks, might become so softened as to offer scarcely more resistance than incoherent sand to any abrading force. Now, when the great ice-sheet comes down again over this region with its rock-grinding forces, this decayed surface would be worn away with great rapidity, and the waste delivered to the sea, to be carried by it far and wide. We must not estimate the vigor of action of a moving glacial sheet by supposing it imposed on such a clean-stripped hard rock surface as we now find in the region north of the great lakes, but must consider it as generally acting on a region incoherent from decay for many feet below the surface.

The only material which holds its structure in the sort of slow decay which we have referred to, is the quartz, or other very silicious rock, which may be mingled with the more perishable materials; so that, in the movement of matter into the sea by the glacier, the quartz would be almost the only evaded material which would retain its form. That this hypothesis will reasonably well account for the most prominent features of the Carboniferous conglomerate series, will, I think, be evident to any one who will carefully examine its structure and contents. Wherever it occurs in Kentucky, it consists of thick beds of sand, composed of quartz and mica, with infrequent small bits of feldspar, the whole more or less mingled with pebbles of quartz and felsite, quite unmixed with any more composite rocks, such as granite or syenite. The thickness of this formation varies greatly in different sections in Western Kentucky; except in the pocket-like depression at Dismal Rock, the thickness does not exceed one hundred feet. The pebbles are small and not numerous, and the sand finer-grained than in the other districts. At many points the pebbles cannot be discovered, and the rocks are only recognized by their massive nature and the absence of all marks of life. In Northeastern Kentucky we have much the same features, though the pebbles are more general in their occurrence. As we go southward, along the Alleghenies, this formation increases in thickness, while the size of the pebbles remain about the same. Along with the increase in the thickness of the mass

goes an apparent reduction in its Azoic character, there being more evidence of vegetation in Pennsylvania during this Conglomerate period. When we come to Cumberland Gap, the section containing pebbles exceeds three hundred feet in thickness, though it contains a small bed of coal in the very midst of the pebble-bearing rocks. This thin bed of coal occurs in the midst of some clays which are intercalated in the Conglomerate, and which seems to mark a temporary and local change in the conditions of its deposition. I am unable to offer any other explanation of the southward thickening of this formation in this field, except the fact that the high mountain region of North Carolina, which probably had several thousand feet more altitude than at the present time, is nearer to this section than it is to the northern part of Kentucky. In the distribution of the sediment of the Millstone Grit, this Unaka Island, as we may call the ancient North Carolina land, seems to have had more influence than the Laurentian Island, which lay to the north of the present position of the great lakes.

In Northern and Western Kentucky the Conglomerate period seems to have been followed by a period when the invasions of sand were rarer, and more mud, laid down in brackish water, was introduced into the Carboniferous section. In the Cumberland Gap section the sandstones predominate far more than in the other districts, showing plainly the greater nearness to the sources of those coarse sediments. In Northern and Western Kentucky there were several great invasions of the sea during the formation of the section which follows the Conglomerate. These returns of the sea appear to have brought tolerably deep water in more than one case. These intercarboniferous limestones demand, and will receive, especial attention from this Survey. At present, it is only intended to notice their occurrence.

The whole of the Kentucky section shows, in a distinct fashion, an extraordinary succession of upheavals and subsidences, bringing the region alternatingly above and below the water level. To understand this action, it is necessary to consider the following points:

We know that continents, as a whole, have probably a constant upward tendency, the periods in which their surfaces are borne down being temporary and more or less local. The theory of the formation of continents requires us to suppose that their constant tendency is upward. It is generally accepted that they are the result of the continued loss of heat from the earth, and the accommodation of the outer portion to the diminishing interior. This causes the superficial parts of the earth's surface to wrinkle, as the outer rind of an apple does in the shrinkage necessarily caused by drying. These earth-wrinkles, when once begun, tend constantly to increase in height. All through the history of North America the Laurentian Island and the Unaka Island, which seem to have been two of its principal nuclei, have been rising upwards, by the action of the subterranean forces, to meet the constant wear from the action of the solar forces operating through rain and ice. But in this normal uplifting action there come pauses or reversals of the movement, which demand more consideration than they have received. I have elsewhere endeavored to account for these changes in direction by showing that they may be in part produced by a mere change in the position of the fulcrum point of a see-saw movement in which, on the whole, the land is steadily going up and the sea floor steadily subsiding.* Another cause of subsidence is doubtless the existence of glacial envelopes at various stages of the earth's history. We already know enough of the history of the last ice time to be quite sure that, wherever the ice lay deep, there we had a lowering of the level of the land, which continued some time after the ice had passed away. It seems likely that there was a compensating elevation of the region south of the glacial line, occurring coincidently with the depression to the northward.

Without endeavoring to discuss the important and difficult questions connected with this field of geological inquiry, I will now call the reader's attention to the fact that the evidence goes to show us that the region of the Ohio Valley was a

*Memoirs Boston Society of Natural History, Volume II, p. 337.

vast and tolerably level district, the surface having been made horizontal by long-continued deposition of marine beds. This area of plains had come, at the Carboniferous period, to somewhere near the level of the sea. I am inclined to think, that at this time the northern hemisphere was under the influence of repeated and extensive glaciation. The evidence of this is found in the vast amount of detrital matter set in motion at this time, which apparently much exceeded in amount all that had ever been given to the sea since the organic record began. No period before or since, in the history of the earth, as far as known by us, has equaled the amount of mechanical sediment of this time. If I am correct in supposing that the Carboniferous period was a period of repeated glacial action, we may regard the luxuriant forests as occurring in the mild intervals of that glacial time. We have sufficient evidence that luxuriant forests, consequent on an excessive rain-fall, are possible associates of a glacial period. Without attributing too much importance to these hypotheses, I would sum up my conjectures concerning the conditions of the Carboniferous time as follows: that vast quantities of sand and gravel were thrown into the sea by glacial action. The successive uplifts and depressions, amounting to at least twenty near Cumberland Gap, were due to the changes in the ice-sheet or heavy coating of ice disturbing the equilibrium of the land. The rich vegetation may be accounted for, in part at least, by the abundant rains of that time.*

The Kentucky series of rocks closes with the middle of the Carboniferous period, and it is likely that the highest part of the Kentucky rocks does not extend above the middle of that part of the coal-bearing beds. The whole question of the relation of these beds to the Pennsylvania section is so much in

*It may be objected that the occurrence of coal within the arctic circle militates against this view. I have elsewhere tried to show that it is a natural consequence of a glacial period to so lower the land barriers about the pole that, by admitting the tropical streams, the arctic regions are kept at a relatively high temperature until the barrier of land rises once again. Without the machinery of the glacial conditions I am unable to get any clue to the repeated movements of the land, the great quantity of detritus, which, from its character, must have come from the neighboring granite areas, that are the natural seats of glacial action, or for the evidences of great rain-fall afforded by the carboniferous conditions.

doubt, and will require so much more evidence for its solution, that I do not venture to attach it here. Nor do I regard the contemporaneity of the beds at Cumberland Gap and in Northern Kentucky as sufficiently established. All the experience of the officers of the present Survey goes against the plan of endeavoring to determine the synchroniety of beds by their fossil contents, at least by their vegetable fossils. The geographical distribution of plants over a great section, even in very uniform forests of the Carboniferous period, makes this a dangerous method. In the hands of the great master of the subject, M. Lesquereaux, its results are not always satisfactory; and for the practical work of the field geologist it has relatively little value.

I very much doubt if a single one of the beds at Cumberland Gap can be traced through to Western Kentucky, and but few will find their determinable equivalents in Northern Kentucky. There seems an ideal reason why there should be some sort of identity between these beds at different points; but when we come to determine it in a practical manner, it is found quite difficult, if not actually impossible, to make sure of the identity.

The only beds above the carboniferous, which have been seen by this Survey, are the beds previously referred to in the region bordering the Mississippi. The general character of these beds is such as would be given by formation in fresh water lakes. The only consideration I shall advert to here is as to the method of inclosing a fresh water lake at this point. May it not be that, while the glacial period by its ice sheet caused the northern regions to sink down, the southern belt of land was coincidently uplifted? If this be the case, then it is quite possible that, during some of the Tertiary periods, this section was converted into a fresh water lake by the upheaval of the land to the southwards. I have long been obliged to conclude, from the phenomena of our coast line, that the belt south of the glacial line went up when that within the ice belt went down, and in turn sunk down when the ice-worn region, relieved of its weight, came again above the sea.

Having rapidly glanced at the remarkable succession of the phenomena of our Kentucky series, and endeavored to give some conjectures as to their meaning, I propose now, in closing, to note some points of a general character as to the origin of these sediments and their value as evidences of the geography of the times when the rocks they composed were laid down on the floor of the sea.

By reference to the several reports of the chemists of this Survey, it will be seen that there are a great number of beds in the State composed of materials containing a large proportion of soda and potash. Attention has already been called to the presence of considerable quantities of mica and quartz in the coarser sediments, such as the sandstones. These facts go to show that this region received a large share of sediment of the original granite centers of the continent, though these centers must have been more than five hundred miles distant on the northern and over one hundred miles on the eastern face of the State. That there were powerful transporting agents at work in this section is sufficiently shown by the great distances traversed by these waste materials.

All the coarse-grained rocks after the Cincinnati Group increase in volume as we approach the Unaka Island. In that group we find, as we approach the position of the Unaka Mountains, that the limestone becomes converted into a fine-grained shale of a red color, containing only small tribolites, just such an assemblage of characters as should be found in beds deposited in deep sea conditions in the formations answering to the Potsdam sandstone and Calciferous sand rock. So far as I have seen them, there is a remarkable absence of sandstones, which I cannot think could well have occurred had the Unaka Mountain Island been above the sea only forty miles away. I therefore venture to doubt whether this mass came above the sea until after the Cincinnati period. After that time every period except the Ohio shale shows the effects of its nearness to that mountain. The absence of any mark of mechanical detritus in the case of the Ohio shale leads me to think that that Unaka Island may have been again

lowered below the sea, or in some way separated from the waters in which this shale was deposited.

CHAPTER III.

We come now to consider the events of that great succession of periods of which no distinct record has been left to us, owing to the fact that the State was above the level of the recording sea. On the west of the Mississippi we have evidence of several fresh water deposits, which hold large quantities of remains of animals of early Tertiary age. Along the banks of our rivers many such deposits must have been formed in each of the successive ages; but while the region of the *Mauvaises terres* and other western Tertiary localities have been exposed to a comparatively light rain-fall, and consequent slight erosion, this Ohio Valley has probably always been the seat of very active erosive forces ever since the formation of the Appalachian chain, owing to the large rain-fall that must have been always brought by the counter trade-winds. In the olden time, when the Appalachians had probably double their present height at least, the rain-fall would have been much greater than it is at present. Owing to this great and incessant wear, the records made in fresh water lakes and beds bordering the rivers have been all swept away within a short time after their formation. There are but two or three points in the State where there seems to be a chance of finding Tertiary deposits of any considerable age. These are in the detached bluffs along the Mississippi river, which have not as yet begun to be examined. It will be only a fortunate accident that can give us their animal remains of any considerable antiquity, so great and incessant has been the erosive action of the Mississippi. The only hope we can have of getting more records of the land life of the remote past of the Ohio Valley is in the deposits made in the caverns which are so plentifully interspersed throughout the State.

In the first volume of the Memoirs of this Survey, I have endeavored to give some facts and opinions concerning the antiquity of the caverns and cavern life of Kentucky. There seems no good reason to hope from them any records that will carry us back further than the early part of the Miocene period, if so far. The rate of erosion in this country at the present time is carrying the surface downwards at a rate which cannot be reckoned at less than one foot in seven thousand years, and probably much more rapidly; so that the uppermost of these caverns known to me in this region cannot well have an antiquity exceeding two million of years, which does not probably take us back of the Miocene period. No extensive excavations have as yet been undertaken in this cavern district. In order to make this search profitable, a thorough preliminary reconnoissance should be made, with a view to ascertaining where there is the greatest likelihood of success. It is manifest that the best chances will be found in the uppermost set of caverns, or, better still, existing in the crevices which are sometimes found in the summits of hills where the old caverns have lost their roofs, and only the accumulations formed in their halls remain to attest their former existence. It will be only after the most detailed study of the State, that there will be a sufficiently accurate knowledge gained to search these records with intelligence. When we consider, however, that the whole surface of the limestone districts is scattered over with sink-holes, that, to the number of hundreds of thousands, afford a sort of trap for the capture of the remains of land animals, which are swept down into the caves beneath; when we, furthermore, consider that, by the action of mud-accumulation and stalagmitic growth, the upper level of caverns is always tending to closure, it will be readily seen that a vast amount of the remains of the land animals which have lived in this district must be entombed in its caverns.

We get some idea of the later stages of the land life of Kentucky from the beds which have been formed by the salt springs or lick deposits of the State. Big Bone Lick, the

most extensive of these accumulations, has a world-wide celebrity on account of the occurrence there of remains of gigantic mammals of extinct species. The great importance of the record it has preserved for us makes it desirable to give some better account of this, as well as other deposits of a similar nature, which I shall now proceed to do.

The fact that, during the period of the calciferous sand rock, there was a considerable deposit of salt in the region about Cincinnati, has already been remarked in a preceding chapter of this report. This store of saline matter remained intact during all the time when the superincumbent beds were wearing away from this surface. Now, that the level has worn down near to the calciferous sand rock, the surface water penetrates into this formation, and works up again to the surface at various points, always in the bottoms of the valleys, making saline springs. Owing to the circumstance of their discharge in the lowest level of the valleys, these springs frequently form a boggy place around their mouths. At times these bogs are extensive and the mud many fathoms deep. Big Bone Lick, in Boone county, is the largest and most famous of these licks. There the saline waters come up at various points over an area of about sixty acres, as rather large springs, each of which, unless artificially confined, oozes out through a large boggy area which may be fifty feet across. These springs have been liable to changes of position—much of the area that is now hard ground bearing evidence of having been at one time in the soft state which is now peculiar to the points immediately about the springs. The valley of the creek in which these springs lie is widened at the point where they occur to an unusual width. The neighboring table lands have a height of about two hundred and seventy-five feet. At some points near the base of the escarpments of the table land there are indications of disturbance in the limestone rocks, which can only be accounted for on the supposition that these springs have gradually carried away in a dissolved form a great mass of matter from the underlying rocks, thus bringing about subsidences in the

section. I am inclined to think that the annual waste from these springs amounts to something like four thousand cubic feet of solid matter per annum. When we come to reckon this back for only a few hundred thousand years, we are forced to the conclusion that these springs must have taken out a great deal of matter from a large extent of territory.

These springs, when first visited by the white man, presented a surprising spectacle. All around the springs the ground was trampled bare by the myriads of buffalo that resorted to their waters for salt. In those trodden grounds lay quantities of bones of gigantic size belonging to the extinct elephants of this region. The fact that these bones lay loose upon the surface is to be explained by the incessant trampling of the buffalo and by the stream, which, at its flood, sweeps over this lowland, excavating the low banks in which these bones lay buried. The successive collections made at this point, during the last part of the last century and the early part of this, have been so large that we must reckon the amount of bones originally exposed at tens of tons in weight. There doubtless still remain the fragments of many thousands of individuals entombed in these swamps. These remains are generally comminuted by the treading of the living animals, often worn to mere pebbles of bone. I do not believe that any perfect animals are likely to be found in the swamps near the springs. At the very top occur the last that died, the bones of which were not trodden by any gigantic animals. Lower down we have only remains which have been ground as in a mill by the feet of their struggling kindred.

It is only at points remote from the springs, where the beds seem to have been formed by a mixture of the creek mud and the waste from the springs, that we find the remains in the order which will enable us to form some opinion as to the succession of occurrence of these animals at this point.*

After a good deal of necessary exploration I succeeded, in 1868, in finding one place where there seemed to be a dis-

*See Appendix to the Memoir of Mr. Allen, in the 1st volume of the Memoirs of this Survey.

tinct order of succession. At this point, at eight feet from the surface, I found *Elephas*, supposed to be *E. primigenius?* and *Ovibos* (*Boötherium*) *cavifrons*, and finally *Mastodon ohioticus;* above the *Mastodon ohioticus*, a horse, seemingly perfectly comparable in age with the mastodon, as far as all indications derived from its condition, and indistinguishable in its teeth from our domestic horse; the caribou, and possibly elk—the former proven by its horns alone—also the bones of the *Bison latifrons;* above these the common buffalo, the bones of which are not found at any great depth, except in the bog about the springs. While retaining a good deal of doubt as to the certainty of this evidence, I am inclined to think it likely that the mammoth (*Elephas primigenius?*) came before the mastodon, and was extinct or nearly extinct some time before the latter beast had begun to fail. With the mammoth we had the large *Ovibos*, called *Boötherium* by Leidy. I find no trace of its remains near the surface. The only point I deem well proven is, that the musk ox and the caribou did not come into contact with the recent buffalo, but were extinct before it came here. It is also pretty certain that the *Elephas primigenius* and the *Mastodon ohioticus* were both anterior in date to the buffalo, and it is sufficiently proven, on other grounds, that the mixture of their bones here is clearly due to the degradation of the original deposits and the consequent displacement of the bones of the elephants.*

It is in the highest degree desirable in the interests of science that these licks should be worked to their very bottoms in search of their possible contents. While I cannot hope that we shall recover any remains of a date older than the early Pliocene, we may at least hope for a great addition to our knowledge of the Kentucky fauna during, and possibly just anterior to, the glacial period.

*The excavations were made by me at my private expense, and in part by means furnished by Mr. James M. Barnard, of Boston, who, with the ready devotion to the cause of science and all other forms of human culture, for which he is so well known, shared the cost of the collections then obtained, amounting to at least a ton of bones. These collections are now at the Museum of Comparative Zoölogy, at Harvard University, and have furnished the basis of the admirable memoir on the distribution and history of the buffalo, by Mr. Joel A. Allen, which has just been printed in the Memoirs of the Kentucky Survey.

I have done much work with the hope of determining the relation of age between these deposits and the drift period. There is, however, scarcely anything that can be called certain evidence on this point. The drift beds do not reach south of the Ohio in this part of the valley. By a judgment, based on the appearance of the wear which has taken place since the glacial period and since the deposition of these remains, I have come to the conclusion that they are of about the same age. The evidence derived from other sources is sufficient to prove that both these elephants survived the closure of the main glacial action for a very long time; so it is likely that they overlapped that time in this district as well, and may have continued down to a relatively recent time. It is probably in this belt of country, just south of the southernmost line of glacial action, that the mass of creatures driven south by the ice-sheet remained, until that great invasion began to retreat to the northward.

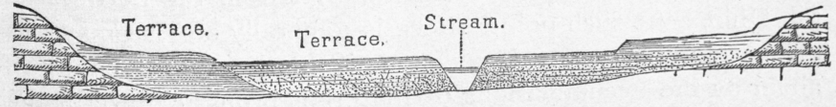
In this connection we may notice the river valleys of Kentucky, which have much to interest the student of these remote times. As regards their valley phenomena, we observe, that, while the rivers which discharge into the Ohio from the northward are characterized by having broad troughs, in which the rivers meander across a breadth of alluvial or interval land, those which fall into it from the south have only narrow gorge-like valleys, not averaging one half the width of their northern representatives. This I believe due to the fact that the northern tributaries of the Ohio flow in valleys which were swept by the southern branches of the great continental glacier, while those in Kentucky have, ever since the formation of their present beds, been flowing in channels worn by running water alone. These differences are the characteristic differences of valleys cut by ice and by water. The effect is to give to the northern streams a wide belt of interval land which is gradually built up by the successive floods, and is cut away by other floods only to be built again.

We have north of the Ohio no such extended cañons as are found along our rivers, especially along the Kentucky and

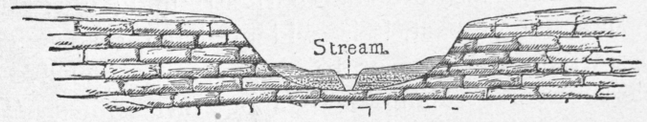
the Green, where for great distances there is hardly a fringe of alluvium to border the stream. Moreover, the southern tributaries of the Ohio flow through much more tortuous valleys; they make, on the average, nearly twice the distance in going a given number of miles of direct course. When valleys have been shaped by ice they run in much more direct lines than when the only shaping agent was running water. This matter is, however, foreign to our present inquiry, which concerns the problems connected with the formation of the river deposits within the State. These deposits along the Ohio are so curious and so varied that they deserve the consideration of a special memoir, which I hope some time to give to their study. I wish here to touch upon some points which may be elaborated hereafter.

The Ohio Valley has the character of width which belongs to its tributaries from the north, though in a relatively less degree. The great Miami, for instance, has a valley about as wide as that of the upper Ohio; and the same may be said of the Sciota and Muskingum; but there is, on the average, nearly two miles of distance between the hills in the section from Louisville to the Chatterawha or Big Sandy river. The section across this bottom varies a good deal generally. It may be typically represented by the following diagram:

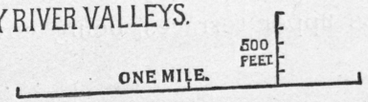
OHIO VALLEY.



KENTUCKY VALLEY



DIAGRAMATIC SECTIONS ACROSS THE OHIO AND KENTUCKY RIVER VALLEYS.

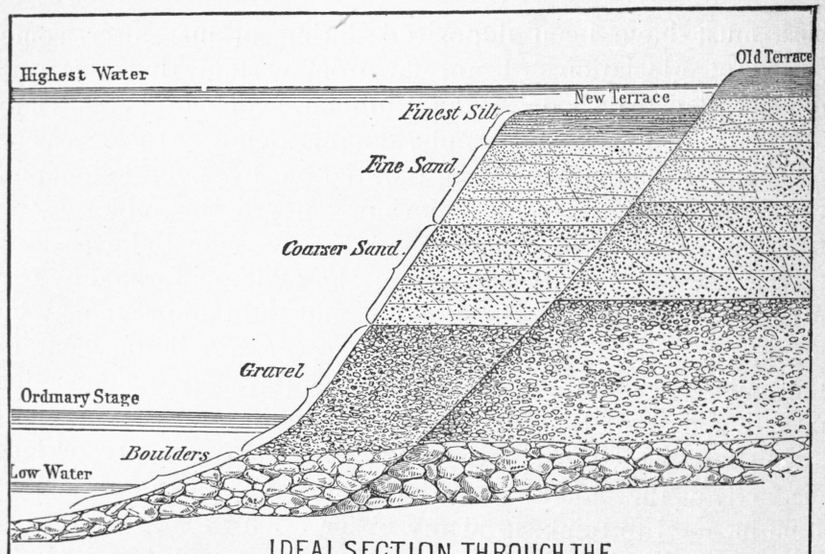


In this we perceive that the table land on either side of the river slopes in an extremely gradual manner towards the main stream. The bluffs, constituting what are erroneously called the river hills, descend abruptly to the plain. The basin consists of two elements, the rock bed and the detrital materials. This rock bed has been plowed out by the stream, working now here now there, in its migrations to and fro over the valley. It generally slopes towards the present bed, because the stream has worked there last. The waste matter or alluvium of the valley tells more of the history of the stream than does the rock basin. The general distribution of this matter is in a succession of terraces, one above the other, and with areas usually proportional to their height above the stream; also the height of these terraces above each other is less and less as we ascend the river. The first terrace lies always at just the high water mark of the floods of the region, for the good reason that the degradation from the action of atmospheric forces is just balanced by the mud laid down by the stream. The other terraces mark the newer deposits. The older they are the higher about the present bed. On these terraces denuding agents have been effectually at work, and they are generally the more exposed the higher they are; so the upper terraces are not often distinctly defined one from the other. These terraces, conspicuous at all points, are most extensively shown near places where the tributaries from the north enter the Ohio. At such points there is generally an erosion circus of considerable area. It seems as if the river has been driven about by the accumulations of materials brought down by the tributaries in such fashion that it is compelled to widen its bed. The conditions at Cincinnati strikingly illustrate this action. In a remote past, it is evident that the stream at this point was driven about so as to excavate an extensive circus, which has an average diameter of about three miles. The remoteness of the time when this action took place may be determined by the height of the terraces above high water mark. Some of them rise to at least fifty feet above that line; yet these upper terraces, being covered by drift of granitic pebbles, must have been deposited during, or just after, some period of glaciation. I am far from certain that this was the last glacial period. I shall, indeed, endeavor hereafter to show special reasons for doubt on this point. It seems very probable, as has already been pointed out by several students, that the great Miami at one time entered the Ohio at the Cincinnati circus; in which case we may regard the part of this area which is on the north of the Ohio, as formed by the Miami, rather than by the Licking and the Ohio. It may be given, as a general rule, that wherever a tributary enters the main stream, there is just such a terraced plain as lies on either side of the Licking at its mouth; and is also found at the mouth of the Kentucky, the Scioto, and more or less distinctly at the mouth of all the other tributaries of the Ohio. I am inclined to think, from my observation of other streams, and such good maps as I can obtain, that it is not peculiar to this stream, but belongs of necessity to every river system. These excavation areas are probably due to the interaction of the currents of the two streams in several ways. In the first place, the tributary has generally a far more rapid current than the main stream, and consequently deposits a large share of its heavier detritus at its mouth. This tends, in the first place, to shove the main river against the bank opposite from the entrance of the stream. Something of this action is observable at several points along the Ohio river; but the more prominent result is to build bars across the mouth of the tributary stream, causing its currents to be forced now in one direction, now in another, and so wearing out a wide basin at its mouth. It is in these intersections of the main stream and the tributaries that we find the oldest terraces that exist along the main river; those at Cincinnati being, to the best of my knowledge, the highest that occur at any point within the valley.

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We now come to consider the structure of these terraces, and though this varies a good deal, it is essentially uniform.

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IDEAL SECTION THROUGH THE TERRACES OF THE OHIO VALLEY.

The diagram given above will serve pretty well to show the general plan as it is seen wherever a section can be obtained. At the base we find a layer of water-worn pebbles, often of great size, it being not infrequent in the older drifts to obtain pebbles near a foot in diameter, and always profoundly water-worn. In the newer deposits of the Ohio river, the pebbles are probably not anything like so large as in the older deposits, a point into which we will need to examine hereafter. Above these pebbles, and mingled with them, lies sand of different degrees of coarseness and smaller pebbles, the whole being stratified by the action of the water in the way we so usually find in such deposits, the beds generally dipping towards the river, though often irregular in this regard. Above these, and in the case of the lowest terrace, at points, say twenty-five feet above low water, we come at length on the fine loam, which becomes generally less and less sandy as we approach the top of the terrace. Near the top we have generally a sheet of half decayed humus, at various points near the surface, showing the line of ancient soils.

It is a noticeable fact, and one often remarked, that the part of the newest terrace—that still growing, is highest near the river, and slopes back to some drainage, which is generally in the shape of a creek flowing against the escarpment of the rocks in which the stream is excavated. The process of this growth seems to have been generally as follows: whenever the river is diverted from its course, and thereby begins to work with less force against one of its banks and with greater force against the other, the slackening current first leaves there the pebbles of the large size that the stream ordinarily carries; then, as with the extending diversion of the stream the current still further slackens, the materials of less weight will fail to be carried on. As the new terrace gets still higher above the bed of the stream, a finer class of detritus will be laid down on it, until the fine sediment borne near the top of the stream will be the only material lifted to its level. The result is, that, no matter how many times the bank is washed away and filled in again, it will have the same general character.

It is necessary to call attention to certain peculiarities of these terraces, which tell an important story. The second bank at Newport, and at various other points—the bank which has its top about twenty-five feet above high water, contains a good deal of a tough blue clay—a clay wherein the mud is finely triturated, and which owes to some peculiarity a grey-blue tint, which is by no means common in our clays. I have never found this clay away from regions affected by glacial actions. I am inclined to think that it was formed at the time the valley was swept by the floods, which came during and at the close of the glacial period, when, for a great length of time, this valley was the seat of a far more powerful stream than at present. There can be little doubt that the glacial period was a period of greater rain-fall than the present time. In no other way can we account for the making of such a vast ice-sheet and the supply of the great amount of water necessary for its continued movement. There are many facts which go to show that the action of cold alone could not, by

any means, account for the formation of an ice-sheet extending down to Southern Ohio.

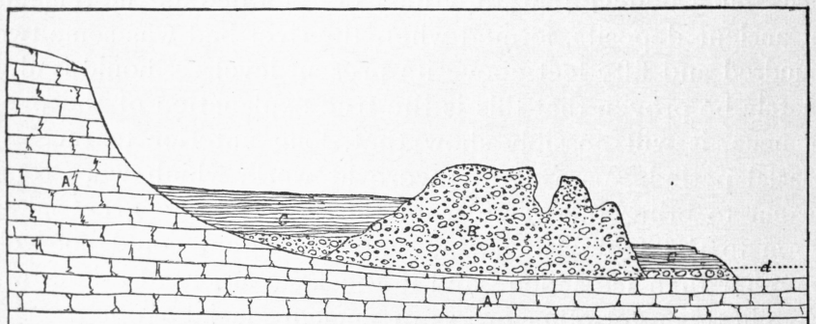
The whole of British America east of the Rocky Mountains has the temperature necessary for glaciation, as has all Siberia, but the deficiency of water makes it impossible for such ice-sheets to form; showing clearly that a considerable rain-fall is necessary to the maintenance of glacial conditions. Moreover, as I have elsewhere remarked, the assemblage of animals living in this country, during or just at the close of the glacial period, makes it quite certain that the conditions favored a luxuriant vegetation, and gave this region a climate in which extreme winter cold could not have existed. These species were all large representatives of their several groups, their great size making it clear that they could not have struggled with difficult conditions. Accepting the glacial period as a time of heavy rain-fall, we can readily account for the width of the Ohio Valley, and for the indications of energetic excavation seen there and in the valleys of its northern tributaries. The entire absence of unstratified drift in the Ohio Valley, and the absence of glacial pebbles on the Kentucky table land, has led me to the conclusion that the ice-sheet never occupied the valley of the Ohio. Some little search on the north side of the river has led me to the conclusion that the southernmost point of the glacier was at some twenty miles north of Cincinnati. I have seen some half a dozen boulders of hypogene rocks lying on the table land south of the Ohio in Boone, Kenton, and Campbell counties; but these were all under six inches in diameter, and rather symmetrical forms; so I have been driven to the conclusion that they were brought to their present position by the aborigines. There are a few facts, however, which require notice in the surface deposits of these counties; facts which, I confess, I cannot readily explain, though I do not believe they are connected with the actions of the last glacial period. In Kenton county, just back of Covington, at a height of three hundred feet above the river, there are a few patches of a deposit which has a thickness of twenty feet or more, and seems to be the completely de-

cayed residuum of some deposit which contained small pebbles of granitic rocks. I propose to make a careful study of these beds, but I believe that they may be regarded as the remains of ancient deposits, formed when the river bed was some two hundred and fifty feet above its present level. Should it ultimately be proven that this is the true explanation of the phenomena, it will possibly show that, long anterior to the last glacial period, some agents were at work, which were competent to bring the waste from the north of the great lakes down to the Ohio River Valley. This agent could not well be other than ice action; and if the facts are read aright, we have in them yet other proofs of ancient glacial action.

Another puzzling set of facts of the same general character is found in the valley of the Licking, at a point called Flatwoods, about sixteen miles south of Newport. There, at a height of one hundred feet or more above the present high water mark of the Licking river, we have in a broad valley quantities of fragments of cannel coal, mixed with bits of sandstone and limestone, the whole forming a coarse breccia. I gathered dozens of these fragments of coal in the course of half an hour's search. I cannot believe that they were brought here by aborigines, for there are no other signs of their presence. I cannot believe that they are the remains of a bed deposited on the spot, but I regard them as material brought here by the Licking river during the time when it ran at a higher level, and when the coal beds were probably far nearer to this place than they are at present.*

Yet another case of the same general character as the preceding is found on the Kentucky side of the Ohio river, at a point opposite and a little below Aurora. The accompanying section gives the most essential relations of this singular mass:

*I am indebted to my friend, General G. B. Hodge, of Newport, Kentucky, for calling my attention to these very interesting facts.



DIAGRAMATIC SECTION of the ANCIENT RIVER CONGLOMERATE and the newer river beds on the Ohio River near Aurora.

A. A. Bed and Cliff Rocks.
B. Ancient Conglomerate cemented with lime.
C. C. Recent alluvial deposits.
d. Level of river at low water mark.

This deposit is a Conglomerate belonging to a time more ancient than the last glacial period, but more recent than the formation of the valley. The mass contains far fewer granitic pebbles than usually belong in the river pebbles. It is clearly stratified, and the thickness cannot be less than one hundred feet. The cement is mostly carbonate of lime, and was doubtlessly derived from springs coming from the neighboring hill; but the geography of the country must have changed a good deal since this action took place. The valley has widened so as to make the invasion of such waters quite impossible. This deposit seems quite without contemporaneous organic remains. It cannot, however, have a very great age, for the valley had been cut down to within one hundred feet of the present level before the deposition of these beds. At no other point in the Ohio Valley have I seen anything like these masses of pebbles.

The cutting rate of the Ohio since the glacial period is approximately determined by the height of the highest terrace containing pebbles carried, from north of the St. Lawrence,

and of sufficiently recent aspect to be classed as belonging to the last glacial period. I am inclined to think that the down-cutting has been not far from seventy feet since the highest of these deposits was formed. I am satisfied that it is at least fifty feet. This may represent the time back to the beginning of the glacial period, or at least to its early stages. As there is little reason to doubt that the average erosion rate in the Ohio Valley is as much as one foot in three thousand five hundred years, we can reasonably suppose the post-glacial erosion of this new bed may be as much as one foot in, say two thousand years, or about twice as fast as the average erosion of the whole country. This would give something like one hundred thousand years as the time which has elapsed since the stage of the glacial period, when these upper terraces were deposited.

The upper terraces of the drift contain very often the bones and teeth of *Elephas primigenius*, the latter in a good state of preservation. From a terrace in the city of Newport, about twenty-five feet above high water mark, at a depth of forty feet, a molar tooth of this species was exhumed which was but little worn by water action; so there can be no doubt that this terrace was formed during the mammoth period. I have never heard of this class of remains in the last or lowest terrace of the river; on the other hand, I have found in this terrace, buried in some cases several feet below the surface, remains of the people of supposed mound-builder age. About twelve miles above Newport, on the Campbell county shore, there is evidence of an extensive camping-ground, where pottery was made and broken in great quantities. This deposit is buried under some five feet of alluvium. The remains scattered about through this deposit include all our ordinary game animals, which would be eaten by the Indian, except the buffalo—no trace of which have I ever found among the remains of the people of the earliest human age in this State. The position of these remains from the above cited locality indicates no great antiquity. The bank near the river may be worn away and restored several times within a thousand

years. The evidence of antiquity increases as we get away from the present shore; so that remains found buried in the terraces at, say half a mile from the bank, would reasonably be inferred to be older than when they had come from quite near the shore. The only evidence of value, however, is to be found in the height of the terrace above the high water level.

As before remarked, the terraces of the tributary rivers arising in Kentucky are much less conspicuous than on the main Ohio. Although not yet fully examined, these terraces, owing perhaps to the narrowness of the valleys of the streams, are fewer in number and less distinct than along the main stream or its northern tributaries.

I have not been able to find in this Commonwealth any trace of ancient gravels which have come from north of the Ohio—the whole evidence going to show that there has been, within the time that a granitic bowlder can endure near the surface, no glacial action that could bring the northern drift any distance south of the Ohio. The only foreign pebbles which can be referred to these deposits are the pebbles of white quartz. The obstinate endurance of this material enables it to exist long after all granitic and similar pebbles have been swept away by decay. This will make the pebbles of quartz the last surviving remains of the last glacial drift. There are such quantities of these pebbles scattered over the State, that I have been disposed to regard their frequent occurrence as proof that we had the waste of old glacial periods surviving on its surface. I am, however, doubtful whether they are not derived from the several conglomerates which once existed in the recently eroded rocks, especially in the carboniferous Conglomerate, or Millstone Grit.

I propose now to give some general consideration to the soils of Kentucky, with a view to setting forth their most important phenomena, as far as observed, and of indicating the problems which should occupy the attention of the Survey. Although the existence of all civilization, the very power of

the earth to sustain its present population, depends far more upon the character of its soils than upon its bed rocks, they have received relatively little attention from the students of nature.

As is well known, a soil, whatever be its character and origin, is composed in the main of the waste of the rocks which constitute the surface of the earth. Its possible fertility, if not its actual fruitfulness, depends almost altogether upon the chemical and mechanical composition of these materials. The vegetable and other organic matter may be readily lost or gained; but the components, which come from the rocks, give the essential character to the soil.

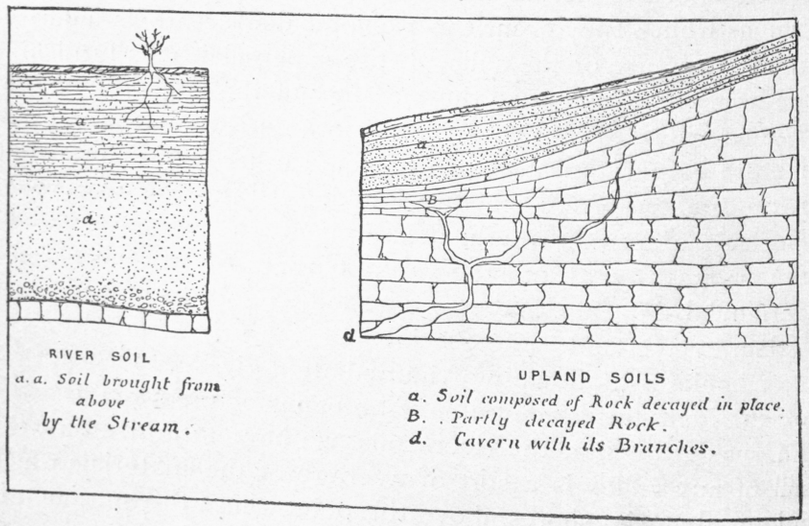
For the purposes of description, soils may be divided into two classes, viz: those of immediate and those of remote derivation. The first of these groups, the soils of immediate derivation, includes all those soils which owe their components to the decay of the rocks which immediately underlie them. The second of these groups includes all those soils which have been composed of materials brought from a distance, and do not at all depend on the underlying rock for their character.

Soils of immediate derivation may be regarded as parts of the rocks of the district, modified by eroding agents. In those regions where they occur, the geological structure is indicated by the structure of the soils—these superficial beds furnishing the best possible clue to the geology of the country. In the regions where the rocks are of remote derivation, they always indicate rather the structure of some other region than that of the country where they are found. All the region covered by glacial deposits, whether retaining their original composition or rearranged, and the valley borders of streams formed by alluvial deposits, may be regarded as soils of remote derivation. Save under the glacial belt, the soils away from the river banks are normally of immediate derivation. Such they are in Kentucky, except along the banks of the streams.

Considering first the river soils, we have to notice that the soil of any valley is a sort of average of the materials which belong along its shores, above the point where the specimen is

taken. Along the Ohio, for instance, where at every point we find a soil derived from a very great variety of formations, there is little difference in the character of the alluvial lands, throughout its course, within the State of Kentucky. This is not the case on the smaller streams. The valley lands of the Licking, for example, are rather poor as long as its waters lie within the rocks above the Silurian, and very steadily increase in fertility as we penetrate further and further into the Paleozoic section.

The alluvial lands of the lower part of the Kentucky river are much richer than the Licking. It is not necessary to follow this into details with the other streams; but I wish to indicate the general principle that the average fertility of any valley may be determined by the character of the rocks whence the alluvium is derived. The peculiarity of these river soils is their depth at every point. They have about the same inorganic contents. Every part of them is capable of sustaining life. The relation of soil and subsoil does not exist here with the same clearness that it does in the soils of immediate derivation. The comparative sections are generally more or less as given in the accompanying figure:



RIVER SOIL

a. a. Soil brought from above by the Stream.

UPLAND SOILS

a. Soil composed of Rock decayed in place.
B. Partly decayed Rock.
d. Cavern with its Branches.

When the soils of the Silurian limestone are studied, it is then seen that the mechanical conditions, as well as the chemical constituents of the soils, vary exceedingly at different points in the section. Generally the virgin soil is divisible into several sections. The topmost is characterized by a loose texture, caused by the long-continued penetration of roots, which, by their decay, give the soils an open texture, and facilitate the passage of water. From this point downwards the insensible change carries us through more and more dense matter, until we come to material which retains the stratification of the limestone, being, in fact, the original bedding out of which the lime has been entirely washed and the other matters, left from the leaching, packed into narrower compass by the pressure of the overlying beds. I believe the shrinkage from this leaching amounts, in many cases, to more than eighty per cent., so that six inches of argillaceous sandstone may represent a bed originally more than one foot in thickness.

Penetrating through these arenaceous foundations of the soils, the streams, whenever there is a limestone base, gather themselves into subterranean courses, which are dug out by the chemical and mechanical actions that gives us our caverns.

The enormous area of these caverns, their evident continuous growth from an antiquity of hundreds of thousands of years, the great thickness of these slowly-leached soils, all together give us proof of the antiquity of something like the present conditions in Kentucky. If the forests, or, at least, the vegetation, had ever been interrupted, it would have necessarily led to the stoppage of the leaching of our limestones and the arrest of the growth of our caverns; for the eroding agent, both in soil and cave, is the carbonic acid derived from the decaying vegetation and absorbed by the water.

The under-drainage of a soil is evidently the first condition of its great fertility. Soils of immediate derivation are only thick where this underground system of waters is well developed; but it is evident that this process of gradual decay must be exceedingly slow.

CHAPTER IV.

DYNAMIC GEOLOGY OF KENTUCKY.

Hitherto we have considered the rocks which are visible within the Commonwealth, and the forces engaged in the transportation of the materials which compose them. We are now to turn our attention to an entirely different class of facts and inferences, viz: to the nature of the forces involved in producing the dislocations, the faults, folds, and earthquake movements, or the general tilting of the rocks which may have occurred within the State.

All of these actions are dependent on conditions which are brought about far below the limit of our observations. All we can ever know of the forces which bring about the earthquake or the mountain ridge, is through inferences made from our study in the laboratory, or from the examination of rocks which once laid far beneath the surface, but which have come to the surface through the action of elevation and erosion.

The various forces, which, originating in the unknown depths of the earth, are propagated to its surface, may be divided into two classes, as follows:

1. Forces which are connected with the translation of heated matters, from the interior to the surface, such as volcanoes and solfataras (or cold gas volcanoes).

2. Forces which manifest themselves only by dislocations of the superficial rocks—dislocations which may be only temporary, as in the surgings of the earthquake, or permanent, as in the foldings of a mountain chain.

This classification is, as I am well aware, only a convenient method of assembling phenomena, with which we have necessarily but little acquaintance; but it will serve to distinguish two sets of accidents which have different fields of action, and probably somewhat different causes of origin.

The first of these causes is unknown in Kentucky. The general law that volcanoes are universally limited to the sea shores, never occurring more than two or three hundred miles therefrom, secures us from any risks of such accidents in this

area. Not only is this region without any trace of modern volcanic action, but there is every reason to believe that at no time within the vast period recorded in its great stone books has it ever contained any of those volcanic events which are so prominent a feature at many points on the earth's surface, and which at one time or another have been developed over almost all of its land areas. Many countries, which now are quite free from such accidents, were at other times completely riddled by volcanic chimneys. Great Britain, Germany, and France, which have never seen a trace of eruption in the historic period,* have all over their surface the scars of ancient volcanoes. But Kentucky and the neighboring districts of the Ohio Valley give us a region—the largest known in the world—characterized especially by the entire absence of all marks of igneous action. I do not know of a single mark of volcanic activity in the area of two hundred thousand square miles, with Cincinnati as a center. I very much doubt if there is a single dyke of igneous rock within two hundred miles of radius from that city.

But the subterranean effects of the heat of the earth, the squeezing and folding forces which lift up rocks into mountains, and in so lifting break great sections asunder, have left abundant marks upon the surface of the State. Those marks do not by any means indicate all the discharges of internal force which have come to the surface; for, as we shall see, the wonderful earthquakes of 1811–13, despite the fact that they shook the State to its furtherest borders, and made the whole continent tremble, left scarce a trace on the surface that is visible to the present day.

As our studies will be limited to the dislocative forces, I propose to divide our considerations into those which concern dislocations proper, faults, and folds, and afterwards to take up the phenomena of earthquakes, so far as they are illustrated by the shocks which have taken place within our border.

*Saving *possibly* Central France.

The dislocation phenomena of Kentucky are a part of a system of disturbances which cannot be understood by the study of the area found within the State alone. They have been brought about by the building of the whole continent; and, to be properly studied, must be taken up as problems in the general architecture of North America. It is out of the question to give any such general study to these questions within the limits of this report. Moreover, the structure of the mountain system of the Appalachians is a problem which is not likely to be solved for a century to come. The most that can be done by the Kentucky Survey is to determine its features within the limits of this State, and to show how they bear on the general question of its origin and structure.

The studies which I hope to see made on this system, as developed within the State of Kentucky, have been but begun, and it will require years to bring them to anything like completion. There are, however, a few points which seem to me sufficiently well observed to warrant me in giving them a place in this report.

I shall first consider the Cincinnati axis, as that is most distinctly a Kentucky problem. This axis is essentially a very broad mountain fold, beginning on the north near Lake Erie, and extending southwardly across the whole of Kentucky and Tennessee to Alabama, having a total extension of near six hundred miles. Its general course is not far from north 20° east to south 20° west; but owing to its great width, and the consequent indistinctness, it is not easy to assign it a definite compass course. The width, as compared to the height of this ridge, is singularly great, and makes it, as far as my knowledge goes, quite unexampled among such elevations as far as they have been described; for while the greatest height, measured from the depression on the eastern side, does not exceed fifteen hundred feet, the width is not far from one hundred and fifty miles. This height is, of course, not the geographical, but the geological height: *i. e.*, the extent to which the beds of rock have been thrown out of their horizontal position. It is difficult to determine the

exact height or width of this ridge on account of the indefinite character of its curves. I have preferred to take the deepest part of the synclinal lying between this ridge and the Pine Mountain, or the other westernmost outliers of the Alleghenies, as the basis from which to measure. This depression, which I shall call the Ohio synclinal, gives a better basis for measurement than the western slope of the anticlinal, which falls away in an extremely gradual manner into the Mississippi basin. The Ohio synclinal is, as are most synclinals, in no sense a valley.

The height of this anticlinal varies materially at different points, as in many other mountain ridges which are closer to the normal type of mountains. This Ohio anticlinal is higher near its extremities than in the middle section. At Lexington this height is as much as fifteen hundred feet. At Nashville it must be about as much; but, at a midway point between these places, the top of the anticlinal has sunk to less than nine hundred feet. The general character of this anticlinal is that of an extremely gradual and uniform curve, with very little accompanying dislocation. The curve at some points seems to be complicated by small variations of height; but I am inclined to believe that these undulations are mere local accidents, and not in any way dependent on the forces which made this broad anticlinal.

Along the Kentucky river, where we have the most elevated part of the ridge within the limits of the State, if not in its whole length, we have a set of dislocations, in the shape of faults, which pretty nearly follow the general trend of the Kentucky river, and have probably been in a measure the determining cause of the course of that stream. The general east and west course of these faults, together with their tendency to open and form places of deposit of veins, shows that they are probably in some way connected with the formation of this anticlinal axis. I am inclined to think that some of the extensive series of veins, carrying galena and other substances, which have been discovered in the neighborhood of Lexington and Frankfort, traces of which are found even to the Ohio river

west of Cincinnati, may possibly be regarded as in a general way connected with the movements which elevated this axis. The tendency of all axis of elevation is to open along their crest, so that the general form of a mountain chain shows us the geological hills cut down to form the geographical valleys, and the geological valleys perched upon the hills. This comes about from the action of the eroding agents, which operate much more powerfully upon rocks that are opened to the weather than upon well-compacted and condensed rocks. It is easy to see that the rocks on the top of the great stone arches will be much pulled apart; they being in no degree elastic, rents must be formed into which the destroying agents, frost and the slow decay which water brings to work on the rocks, will easily penetrate. On the other hand, the rocks in the geological valleys are compressed by the folding action, so that I believe that, given two rocks essentially similar in constitution, the eye can, in many cases, recognize the difference in mechanical condition in those two conditions of pressure. Of course the extent of this action must be measured by the amplitude of the folds. In short curves, as in the Alleghenies and most other mountains, the compression and extension are necessarily very great. In a very broad field like the Ohio axis, the extension on the top of the arch would not be very great; but it might easily result in making a number of fissures which would penetrate to a considerable depth.

The exceeding breadth of the Ohio axis, and the great uniformity of the arch, leads me to believe that the thickness of the rocks involved in the movement which produced the axis, was very much greater than usual in mountain folds. An experiment with sheets of metal, or what is better, with sheets of paper of different thickness, will show that the amplitude of such curves is proportioned to the thickness of the material to which we apply the lateral pressure. General considerations will show this to be a law common to all rigid substances subjected to a lateral pressure. If this view be correct, then the Ohio axis indicates that the lateral pressure which has formed this axis has caused the movement of a greater mass

of rocks, in one body, than any other similar ridge which has yet been observed.

I have elsewhere endeavored to show that the wrinkles or folds on the earth's surface, or the movements which indicate lateral pressure, are divisible into two distinct classes: relatively narrow steep folds, which are properly mountain chains, and very broad gradually sloping arches and furrows, which constitute continental ridges and sea basins. There seems to be no series connecting these dissimilar sets of curves, and I have endeavored to show that the continental folds are probably accommodations of an outer solid shell of say one hundred miles in thickness, possibly less, to the great central mass diminished by the loss of heat; while the mountains arise from the contractions which have taken place in the outer crust itself. The great width of the Ohio anticlinal axis makes it more like a connecting link between mountain and continental upheaval than anything else I have yet seen; yet I am satisfied that it should be classed with mountain folds.

I have already discussed, in a general way, the period of formation of the Cincinnati axis, in the general account of the history of the rocks which we can observe upon its sides. We have in that history no distinct evidence as to the time when its final elevation was accomplished; but from the general want of pebbles in the rock formed during the coal period, (which is composed of materials brought from a great distance,) I am inclined to believe that it was not out of the water at the time of the latest formation known in that district, though it was probably begun at a very early age. The fact that the rivers of the Ohio system, which evidently wrestle with the Cumberland Mountains, have evidently had no great difficulty in laying their courses straight across the Ohio axis, is a striking evidence that it must have been lifted very slowly to its present height. If it had at any time been suddenly upthrown, it would have barred those rivers and compelled them to make something like the sudden southward turn which the Tennessee is compelled to make in its effort to get clear of the Cumberland chain. The Kentucky river appears

to be a little troubled to pass the barrier; but I believe that this is altogether due to the influence of local faults, which cause the channel to wind about in its passage over this axis. The Cumberland river, on the other hand, avoids the geologically lowest part, and turns to cross the summit of the ridge at Nashville. These facts warrant us in supposing that the development of the ridge has been so gradual that the courses of the streams across it have never been obstructed.

At Wells' river, near Clarksville, and south of the Kentucky line, in the western section of the State, there is another axis of disturbance, which seems to be, on the whole, parallel to the Cincinnati axis, though its direction and other important features are yet to be determined. The considerable southward extension of the western coal field towards the Tennessee line, in Todd and Christian counties, can best be accounted for by supposing that a synclinal of this Clarksville axis of disturbance extends north into Kentucky; it probably also is among the disturbing influences that have greatly affected the western coal field in the region just north of this part of its border. As yet, too little is known of this field to enable us to define with precision the direction of the disturbances which have so greatly perturbed it. I am inclined to think that this Clarksville axis has been the line along which most of the dislocation has been developed.

Incidentally, I have already mentioned the appearance of something like local uplifts in the Hickman and Columbus district, where the Chickasaw bluffs give, by their peculiar isolated character, some grounds for suspecting local elevation. This is also a field where the facts are still to be collected. I am by no means satisfied of the truth of this conjecture, and shall be glad to find that these peculiar ridges are only the remains of an extensive plateau that has been nearly completely destroyed by the wandering river.

Having considered the geological accidents that have given character to the line regions of the State, we will turn now to that small but peculiarly interesting section where the subterranean disturbances are exposed in the form of mountain

chains. As before remarked, this region is but a fragment of that great system of disturbances which, extending from Newfoundland to Alabama, constitutes the Appalachian mountain system. This great system affords one of the most beautiful illustrations of the action of mountain-building forces. In it the action of these forces, at far different times and upon very varied rocks, can be studied with care, without the hindrance of the exceeding structural complications found in the great Alpine system, or by the difficulties of distance which beset the student of the Cordilleras of America.

It is from the Appalachian system that we have the most to hope in the way of information as to the causes that have worked in the building of the earth's feature-lines; and it is therefore a matter of great scientific importance to have every part of this system examined in detail. The Pennsylvania Geological Survey has already given us some studies on the structure of this system; and the revived Survey, under the skillful supervision of its present able chief, will doubtless do much to extend and perfect the work; but it is in a high degree necessary that this investigation should be carried on at a number of different points along the chain; for there are about a dozen different regions along its two thousand miles of length, each characterized by some special method of manifesting the compressing forces. The Gaspé section differs from that of Northern New Hampshire and Maine. The Vermont, Massachusetts, and Connecticut regions form a third division; the Catskill, in New York, a fourth; the Alleghenies, of Pennsylvania, a fifth; the district of Virginia, between the Potomac and the Kanawah, a sixth; the section from the Kanawah to Chattanooga, a seventh, and the Alabama section, where this system of elevations fades out and passes beneath the recent beds, is to be classified by itself, making the eighth.

Parallel to this linear group we have at least half a dozen distinct, eastward, outlying ranges, having the same general direction as the Appalachian system, and entitled to be considered as a part thereof. Of these, the Nova Scotian and

Cape Breton sections are the northernmost; then come the system of Mount Desert, that of the Blue Hills and Eastern Massachusetts; then the Blue Ridge, beginning as the South Mountain in Pennsylvania and connected with the Blue Ridge in Virginia; then the Unaka section, including the highest land in the whole system of the Appalachian. Still to the east we have, in Virginia, the uplift, which I have termed the Richmond axis, where the syenite has been thrust up to form the eastern border of the Mesozoic coal field of Virginia. There are other regions of disturbance which, either by their peculiarities of structure or by the fact that they have been the product of special and limited upheavals, deserve to be given a special name. The limited disturbances of the Martha's Vineyard region, on the New England coast, dating from the time of the later Tertiaries, the Mount Tom upheavals in the Connecticut Valley, the peculiar submerged ridges of unknown age off the Carolina coast, and other local upheaval regions, could extend our catalogue of regional divisions of the Appalachian much beyond the limits of the score of divisions suggested above. It is far from my purpose to do more than indicate the general fact that there are such features as regional divisions in the Appalachian chain, and that it has been the product of many successive elevations acting along the same lines of upheaval. The existence of these successively formed elevations, all having essentially the same direction, needs to be dwelt upon, on account of the strong impression which the theory of M. Elie de Beaumont, concerning the parallelism of mountains of the same age and the diversity of direction of mountains of different ages, has made upon the minds of naturalists. I believe it important that the reader should approach the study of this field without the hampering influence of these opinions, lest the most valuable lessons which may be learned there be obscured by prejudice.

The Kentucky section of the Appalachians is so small that the studies which we are to pursue here will be limited to some of the simpler problems afforded by the Tennessee section of the Appalachians. The action of these mountain-building forces are limited in Kentucky to the region east of a line drawn from the county of Pike, on the West Virginia line, to the Tennessee line, near Jellico. This district does not include more than about five thousand square miles of territory, and only takes in the westernmost features of the Tennessee section of the Appalachian system. It has, however, in Pine Mountain, nearly the whole length of one of the most remarkable of all the mountains of this section, and between this remarkable ridge and the Cumberland Mountain, on the east, nearly one hundred miles of a great synclinal valley, which we shall call the Cumberland synclinal. In order adequately to understand this region, it will be necessary to look a little into the structure of the whole Tennessee section, and notice its relations to the neighboring districts. Enough is known of the structure of the Allegheny or Pennsylvanian section of the Appalachian to make it clear that it is composed of a number of parallel ridges and furrows, lying side by side, so that the east and west section is like a cut across a piece of corrugated roofing. This structure may be called the normal structure of a mountain of simple folds. In it there are few great north and south faults, and they rarely come in to break up the symmetry of the great folds. These folds do not average more than four or five miles in width, and are generally sufficiently distinct to make their original outlines quite recognizable. The decay at the top of the arch, favored by the open structure which, as we have seen, leads to such rapid destruction of mountain arches, has not in Pennsylvania gone further than it has in the Swiss Jura, and the mountain has been, in many cases, simply opened to the action of the air, which has not yet done great destruction.*

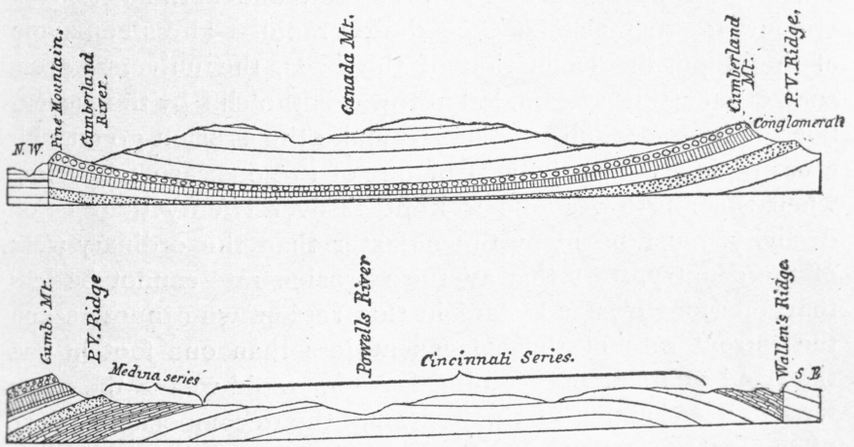
In East Tennessee the conditions, as indicated by the structure of the rocks, is something quite different from that of

*The slight amount of this wearing action in the case of the Pennsylvania mountains, as, for instance, in the Blue Mountain, has led me very much to doubt that the whole of that section has been elevated in times as remote as the Trias. I cannot believe that we could have had the whole of some protecting formation swept away from the flanks of these mountains while the arches have worn down so little. I should feel that the Blue Mountain had not suffered as much by erosion as many mountains of Tertiary age have done. I cannot, indeed, see much more wear indicated by the Blue Mountain, for instance, than in the Puy de Dome, or the other relatively recent volcanoes of Auvergne, in Central France.

Pennsylvania. That we may see these conditions clearly, let us glance at what were the probable circumstances of this region when the formation of the mountains began. There is very little doubt that this district was generally, if not uniformly, covered by the beds of the Carboniferous period. These abutted on the east against the great Unaka Island, then probably covered by beds of a later age than those now exposed there. When the movements of the uplift began, time does not show the pebbles of the old granitic rocks now exposed thereon. When the movements of the uplift began, this ancient island would naturally yield less than the low-lying beds on either side. It seems to have acted as the Blue Ridge has acted throughout its length, to confine the movement to the regions west of its mass. Whatever motion was given to it, probably followed the ancient lines of fracture, which may exist within it; but they did not result in making typical arches of the Allegheny forms.

The movements on the west of the Unaka axis seems, at first sight, quite unlike the ordinary Alleghenian dislocations. If the geologist looks from the summit of the Cumberland Mountains over the far-extending mountain region of East Tennessee, he beholds line upon line of bold rocky walls, which fill the field of view. Away to the east the Unaka range, and the neighboring mountains of North Carolina, bound the horizon with a high, serried range of crests, whose varied outlines contrast strongly with the even ramparts of the newer ridges of the Tennessee Valley. Looking closely at these ridges, we find that, with the exception of the Cumberland range, they are one and all produced by the action of faults; and their lines indicate the existence of a wonderful series of breaks, extending for a distance of more than one hundred miles in some cases, and, in more than one instance, of singular uniformity of height. In the whole section there is but one distinct anticlinal—that on which the ridges of Cumberland Mountain stand—and one distinct synclinal—that through which the Cumberland river flows in that part of its course which lies above Pineville. The structure

can best be explained by supposing, that, in the elevation, the tendency was to form a great anticlinal some fifty or sixty miles across, and that it was unable to support itself, and the sides of it fell, in a succession of longitudinal strips detached by the parallel faults; and the only part retaining the anticlinal character being the section of which Cumberland Mountain is a part. The eastern retreat escarpment has been destroyed by faulting. It will be seen by the diagram given below that this escarpment has retreated a great distance from the central axis of the anticlinal, being several miles back from that line:



It is a striking fact, that there are no outliers of the riven beds scattered over the mountain valleys. Several of the walls of the faults have worked back some distance from the point of fracture; but in most cases they are still close to the point where the break was formed. This is most conspicuously the case in the Pine Mountain, which, throughout its whole length, has its escarpment within a few hundred feet of the break where it was first found. It is only necessary to consider what is going on along the faces of cliffs, such as are exposed on the steep walls of Cumberland or Pine Mountains, to be convinced that the process of retreat, under the action of eroding agents, must be exceedingly rapid. The steep angle of the slope, the inclination of the beds, the universal presence of a cutting stream, led in towards the cliff by the inclination of the strata, all combine to make the erosion go on with great rapidity. The retreat of one of these escarpment faces, when the angle of slope is kept at over twenty degrees of declivity, must be many times faster than the ordinary wear of the country. As this average erosion rate cannot be less than one foot in 3,500 years in this region, we cannot reckon the retreat rate of these faces at less than one foot in one thousand years.* Everything favors a rapid wear—the great rain-fall, great action of the frost, and the decomposable nature of the materials.

I find it difficult to believe that the present rate of retreat of the escarpments of Pine Mountain is as slow as that given; but, even at this rate, the retreat would be one thousand feet in a million years; and the estimated duration of the Tertiary time, which by no reckoning is made less than four or five million of years, would cause a retreat of these erosion cliffs about a mile in distance from these points of origin. On Pine Mountain, at several points examined, there was not one half of this distance between the summit of the cliff and the downthrow side of the fault. What makes this the more re-

*The erosion rate is determined by the following co-efficients, the amount of rain-fall and frost action, the resistance of the materials due to their composition, and the attitude of the surface.

markable is, that this fault, like all others, is not vertical, but probably has a considerable dip in the same direction as the slope of the escarpment.

When we look at the Cumberland anticlinal, swept clean of its upper beds for a width of many miles, and then compare it with the Pine Mountain fault, we are driven to the conclusion that the formation of the fold must far ante-date the existence of the fault. The same argument will convince us that many of the other faults in this section of the Appalachians are to be regarded as belonging to a relatively late time, though I have seen no such proof of newness as Pine Mountain affords. It is in a high degree desirable that accurate sections on a true scale should be made across the section between the Unaka Mountains and the western border of the Appalachian disturbances, with a view to getting accurate information on this subject.

The existence of these relatively modern breaks in this ancient chain requires us to suppose the continuance of disturbances down to a very late date. All the subsequent disturbances seem to have taken the shape of faults rather than folds. The cause of this is uncertain; but, without entering upon an attempt at an explanation, I would say, that I find in my notes, made during a year of journeying in Switzerland, in 1866–'7, the frequent remark, that the Alps were completely girdled by just such a belt of faults as we have here. Subsequent studies on mountains have satisfied me that there is some necessary connection between the occurrence of faults and the action of this mountain-building force in the immediate neighborhood of an ancient and massive mountain region. The effect of mere weight on the development of those curves of the crust, and the possibility of their formation being arrested or modified by weight alone, is very well shown in the condition of the Cumberland anticlinal, as it, in its southward extension, comes against the massive Tennessee table-land, where, as my learned friend, Dr. Safford, has shown me, the thickened and little worn beds of the lower coal measures, conglomerates in the main, have proved too massive to be

involved in the mountain-building movement. If the fold had kept its course, it would have had to crumple this mass into its curves; but it seems to have been turned abruptly to the east and shortened to half its breadth, if not quite extinguished.*

An interesting inference, as to the ancient conditions of this district, can be made from this effect of the Tennessee table-land on the course of the Cumberland anticlinal. This inference is, that this table-land has existed, in something like its present relative thickness, from a very ancient time. If many thousand feet in thickness of beds had been removed from this country since the formation of this anticlinal, the chance of this table-land having its relatively massive structure would not be great. This is an argument for the relatively recent origin of this part of the Appalachian system. The Pine Mountain fault, also, disappears against this massive fragment of the ancient carboniferous table-land.

The great synclinal of the Cumberland lies, for most of its distance, within the State of Kentucky, its western boundary being the unbroken line of the Pine Mountain, its eastern side being bounded by the slope of the Cumberland anticlinal. This synclinal is by no means a simple, unbroken trough, but is filled with minor but most interesting accidents in the shape of cross-faults and transverse axes of elevation. In the neighborhood of Cumberland Gap, these transverse faults and axes give a most complicated geological structure. At a point about midway of the valley, on a line from Pineville to the Gap, we have a beautiful example of a half dome, formed by an arched upthrow on one side of a fault, known as Rocky Face.†

Many of these faults pass completely through the Cumberland escarpment, or Cumberland Mountain, as it is commonly called. Cumberland Gap is formed by the erosion caused by

*This wonderful section deserves, and should receive, the most careful study from our American geologists. I have seen only enough to fill me with desire to learn more as to its structure. I am sure it is more likely to reward the student of dynamic geology than any other district known to me in the whole Appalachian chain.

†Some of these accidents are two complicated for description, and we must await the making of the final map of the district in order to represent them in any adequate fashion. The want of such map compels me to omit all mention of the details of structure in this most interesting region.

one of these faults, which traverses the ridge in an oblique manner, the downthrow being on the west side of the fault line. A mile further, to the southeast, apparently on the continuation of the same fault line, we find another evidence of faulting in what is called Double Mountain. Here, again, the crest has retreated but very little from the fracture line, showing the recent character of the break, which must, indeed, have happened long after the topography had taken on its present general character. It seems likely that the series of breaks, which opened the passage of the Cumberland through the Pine Mountain at Pineville, formed the half dome at Rocky Face, cut the Cumberland Mountain at the Gap, and formed Double Mountain, are either on one and the same fault line, or constitute a series of faults closely related in direction.

Following the line of the Cumberland to the south, as far as Big Creek Gap, about forty miles from the Cumberland Gap, we come upon an exceedingly interesting portion of the mountain. The usual dip of the beds in the mountain is from thirty to forty degrees of declivity. It is noticeable, along the sixty miles of its length that I have seen, that the direction of the mountain, as determined by its rate of retreat, varies with the angle of dip. Where the dip is steep, the mountain has retreated rapidly to the west, and the crest is low; where gradual, there is almost always a salient angle to the east, and the crest of the ridge is high. At the Big Creek Gap, however, the whole section, from the base of the Cincinnati Group to the base of the Conglomerate, is positively on end, so that the whole of this section can be crossed in traveling a distance no greater than its thickness; yet the line of the mountain is not perceptibly deflected from its general trend. At Pennington's Gap, as shown by the reconnoissance of Assistant Moore and Messrs. Davis and Eldridge, students of the Summer School of Geology, made in 1875, the same arrangement occurs. In the case of the former of these two localities, at least, I am satisfied that the dislocation has taken place, since the general trend of the escarpment has been essentially the same as it is at present, otherwise the uniformity of the align-

ment of the whole ridge could not have been brought about. It would have been quite impossible to have had the conditions just what they are at present, if this structure existed here before the retreating escarpment came to occupy its present place. The coincidence of water gaps through the Cumberland, at the two points where these vertical sections occur, is also remarkable, and points to the conclusion that they have been brought about by a profound system of faulting. These faults show, at several points, something of the conditions under which they have been formed, and, in order to understand their structure, it will be necessary to consider the classification of faults in respect to some of their more important phenomena. In the first place, as regards their rapidity of formation, faults may be divided into two groups: those which are formed with exceeding slowness, so that a stream flowing across the fault may not have been interrupted in its course, though the fault may have grown to a great height, the cutting action of the stream in this case being far more rapid than the rise of the fault. A second group will include those faults where the action has taken place with suddenness, so as greatly to affect the neighboring rocks, often crushing them for considerable distances from the fault line.

So far as my observations go, it appears as if the great North and South faults, such as those of Pine Mountain and Clinch Mountain, had been of tolerably gradual formation, though I do not think they have been upheaved so slowly that the rivers have not been turned aside from their courses; but they do not have the appearance of violence that belongs to the transverse faults. The smaller faults, which cross the others at various angles, show at several points, by the brecias that occur along their lines, the violence that attended their formation. The Cumberland Gap fault, for instance, is traceable by a belt of breccia, of ten or more feet wide, that marks its line. This breccia is composed of bits of conglomerate sandstone, with ragged angles, fixed together by oxyde of iron. So far as I am able to judge, these bits of stone are all from the rocks in which they are bedded, being rarely more

than broken to pieces by the motion, and not greatly displaced from their original positions. On the southwest side of this fault, at Cumberland Gap, there is a downthrow of several hundred feet, probably about three hundred, and the beds only gradually recover their place in the face of the mountain after about a mile of distance.

In the Cumberland synclinal, we have evidence of the extreme difficulty which these mountain-building forces had in throwing this surface into folds. This valley, which is about ten miles wide, is almost level throughout this width, and only shows the crumpling action near its borders. The section published with this report does not show all the peculiarities of this singular valley, the details of the small disturbances being quite left out. I believe that this level character is due to the same causes that made the Tennessee table-land completely arrest the Cumberland anticlinal. This cause is either to be found in the thickness of the section or the thickness of the mountain-building forces. As we go south into the Tennessee table-land, we find in the Sequatchie Valley, as was admirably described by Professor J. M. Safford, in his lectures at the Summer School of Geology, in 1875, a complete mountain ridge in the midst of this great area of undisturbed rocks, with great areas of horizontal beds on either side.

Looking at the general section of the Cumberland escarpment, or mountain, as it is called, we notice that the dip of the beds becomes suddenly great at that point, and that there is comparatively little dip on either side. This peculiarity has suggested to me the hypothesis that, possibly, the time of the formation of the Pine Mountain, and probably some other faults, was one of renewed lateral pressure, and that this escarpment, which is separated from the high land of the synclinal, along its whole length, by the valley, had its dip suddenly increased, the whole of the dips in the anticlinal valley being also increased by the movement. I am the more inclined to accept this hypothesis, because the continuation of the present dip lines would carry the arch of these eroded mountains to a

great height—a height greater than I am inclined to suppose they ever had. But the strongest argument for some such supposition is, the coincidence of the occasional vertical dip with the escarpment line. As the rate of retreat of an escarpment is, on the whole, proportionate to the angle of declivity of the beds, being greater with steeply inclined beds than with horizontal beds, there seems little reason for finding this coincidence here, unless it came in the way indicated.

Another point, which gives me trouble to explain, is the relatively intense wear of the disturbed region. After allowing much for the effect of the opening of the rocks caused by their dislocations, there remains evidence of a very excessive erosion. It seems to me there should be more of the coal-bearing series of rocks in the disturbed district of the East Tennessee section than actually remains there. It is likely that this excessive erosion has been, in the main, caused by the powerful river system of this section. It only requires a glance at the map to show that we have there a great engine of erosion in the branches of the Tennessee river, effective at the present time, and probably doubly powerful in the early day, when they were fed from the then far higher lands of the Unaka Island, before they were worn down to their very roots by erosion. It is also possible that this region has been swept by ice streams from this mountain centre on the east, for the erosion is somewhat after the fashion of the wearing which has dug out the basins of the great lakes, when the ice sheet from the Laurentian mountain system came down upon the softer rocks. The East Tennessee river system exposes that region, at the present day, to the most rapidly wearing of any part of this continent. These rivers have considerable fall, and are fed by a rain-fall of at least sixty inches per annum.

Throughout the Eastern Kentucky coal field there are slight indications of dip in various directions, which cannot be reduced to any distinct system. On dip map in Assistant Crandall's report, in the second volume of this series, is a good representation of the variety of these inclinations as regards direction and angle. After a good deal of consideration, I am

inclined to abandon the idea of these irregularities being the result of dislocatory forces. In many cases, at least, they are doubtless due to the difference in thickness of subjacent beds. Both the Sub-carboniferous limestone and the Conglomerate vary greatly in their thickness. This is in a measure true of many sections of the coal beds, so that the beds laid down on these variable measures will necessarily vary a good deal in their inclination. The erosion, whenever it is subterranean—and it has this character wherever there are limestones above the drainage—is sure to give rise to many local dips. This is also occasionally the case in localities where there are clays which can be leached of their saline matters by the action of the penetrating waters. A very large number of minor dislocations, in Western Kentucky, are doubtless due to the sinking of extensive cavern areas.

The strongest objection to the classification of the many minor irregularities of dip, as due to lateral pressure, is, that we require this lateral pressure to act in the very outermost beds of the crust, and we fail to find any sign of the regular arrangement of the folding in determined axes, which is so constant a feature in all cases where we have distinct evidence that the disturbances have been caused by mountain-building forces.

The only permanent feature, in the generally irregular dips of the region west of Pine Mountain, is the southeastwardly inclination of all the beds. This inclination is very general, though slight. From time to time it changes to a northwestern direction, so as to lead me to conjecture that there might be a faint trace of anticlinals parallel to the Allegheny axes; but I have not been able to get any distinct evidence on this point. It will not be until the whole of this section is accurately mapped, and the dips indicated thereon, that we shall have any basis on which to determine this hypothesis.

Summing up the history of the dislocations in this section, we see that the whole of Kentucky, and, in fact, the whole of the section included in the Ohio Valley, is in the grip of those movements which have been building the Appalachians from

the earliest beginnings of the continent. The section of this system which lies between the North Carolina district on the one side, and the Cincinnati axis and Tennessee table-land on the other, differs from the Allegheny section in the fact that faults have, to a great extent, taken the place of folds. These faults in some, if not in all, cases, must be regarded as of very recent age, from the fact that their escarpments have not retreated for any distance from their original position at the time of formation of the fault. The folds, at least that of the Cumberland Mountain, are of a date far more ancient than the neighboring faults. Furthermore, that the great erosion of this district can be, in part, at least, accounted for by the extensive river system confined in this district by the general structure of the country, and concentrating on it the erosive force of the great rain-fall, which the Unaka Mountain system, as well as its own high ranges, must have given to it ever since an early time in the history of the continent; and also, that the curious local disturbances of the beds along the Cumberland escarpment can be attributed to the fact that the difference of weight at this point, between the low-lying plain and the mountain section, caused breaks to be made along its line, from which line the erosion has not been great enough to work back the escarpment since the time when these last disturbances occurred.

We will now consider the action of the forces which come from the earth's interior, in the shape of those tremulous movements which we term earthquakes. It will be seen, in the sequel, that this State has a special interest in this class of actions, having been the seat of the most remarkable series of such disturbances, which has affected this continent within the historic period.

In our ignorance of the cause of earthquake movements—an ignorance which has only begun to be diminished by the latest researches in seismology of Mr. Charles Mallet and others—we have been driven to group under one name phenomena, doubtless, of the most varied origin. There can be little doubt that these disturbances of the earth are of as

various origin as the movements of the air; but to our senses everything is absolutely hidden, except the movement consequent on these varied accidents, and this movement is made uniform in all its features by the laws connected with the elasticity of the earth. The admirable researches of Mr. Charles Mallet have shown us that the earthquake of 1851, in Calabria, and one or two other disturbances, have probably been caused by the sundering of the rocks and the opening of a fissure having a length of many miles and a depth of many thousands of feet, the topmost part of which was about fifty thousand feet below the surface of the earth. This determines one of the sources of disturbance, and undoubtedly this is a very frequent cause of great movements within the earth. The exceedingly great number of these breaks within the earth's crust, which we know to have been formed in the past, gives us an assurance that they are an essential feature in the economy of the earth; so it is quite warrantable to suppose that they may be formed at any time in the earth's history, and at any point beneath its surface. In the cases where there has been good reason to suspect that the formation of rents has been the cause of the earthquake, the area of the regions shaken and the magnitude of the disturbance were both quite small. It is not probable that the vast convulsions which have shaken great continents, or those peculiar disturbances which have given us continued shocks such as we shall now have to consider, were due to the same sort of causes. Our study of the phenomena of the earth makes it sure that change in bulk is one of the most frequent and efficient causes of disturbances. After we get a few hundred feet below the surface, there is probably no part of the mass which is not impelled by powerful forces to either expansion or contraction. When the mass of the material affected by these tendencies becomes sufficiently great, some alterations must take place. It is by no means necessary that these movements shall affect the surface of the earth in any permanent way. The outer few thousand feet of strata may not be disposed to movement, or may be so rigid that the lower shiftings cannot drag it

into their own movements; but the result may be accomplished by a compression of beds at some other point.

I am inclined to believe that these earthquakes, which are characterized by a great and long-continued succession of shocks, occur more commonly in regions remote from recent mountain chains, where the evidence is that the mountain-building forces are at rest, than in the midst of a mountain region where the mountain-building forces may be presumed to be still active. If this be the case—and, after some search through the history of earthquakes in the tables of Perry, of Dijon, Mallet, and others, I have not found a clear exception—then we have something like a confirmation of this hypothesis, which is substantially that adjustments may be effected in either of two ways—by the interior slipping on the exterior, or by the exterior contracting to allow the interior freely to take its adjustments.

There are, I believe, at least three distinct classes of sub terranean disturbances which are likely to produce earthquake shocks:

1st. The contraction of rocks forming crevices which may be filled by molten matter forming dykes, or, in other cases, by the slower action of heated water, constituting veins.

2d. The slipping of rocks over each other under the influence of compressing forces, giving phenomena such as may be observed in mountain chains.

3d. The sudden movement of gases contained within the earth, impelled by great heat to the exercise of sufficient energy to dislocate the rocks that contain them. This last class of causes is probably operative only in the vicinity of points of volcanic activity.

The Ohio Valley has been the seat of repeated slight earthquakes—too slight to demand notice, save as evidences of the existence of earthquake-making fissures. All of these shocks seem to have originated beneath this valley. But a single series of shocks in its whole history have had the violence of a great convulsion impressed upon them. In November, 1811, began a series of convulsions unequaled, or, at least, unsur-

passed, by any earthquakes which have been felt upon this continent. These memorable events are known commonly under the name of the earthquakes of New Madrid, that town on the Mississippi river, opposite the extreme southwest corner of Kentucky, being the most important village within the range of its devastations. In Appendix B I have brought together some information concerning this catastrophe, which may be consulted by the reader desirous of acquainting himself with the general character of the convulsion, and its most important effects. In this Appendix will be found the admirable statement of Judge Fowler, of Livingston county, who seems to have retained, in a very clear way, the impressions made by the events of those days. His account of the invention of the frontiersman for observing the shocks is very interesting, as it furnishes probably the first record of a pendulum apparatus for observations of this description.

The records of this early event in the history of this valley are extremely imperfect in a scientific point of view, and yet sufficient to assure us that the convulsions, for the first part of the disturbance, were of the most violent character. Occurring at the present time, there is no doubt that they would cause a terrible loss of life and property throughout the region where their action was most violent. The only fact bearing on the range of this shock not given in the Appendix is, that, at the town of Leitchfield, in Grayson county, several chimneys of great solidity were overthrown almost to the base.

As this convulsion was so terrible in its character, ruining even the log cabins of that early day, at the points where its action was most severe, it becomes a matter of importance to see what light, if any, can be thrown on the probability of its re-occurrence in this region. Although no certainty, or anything approaching it, can be obtained on this point in the present state of the science of earthquakes, it seems to me that there are some points which are not without value in helping us to a judgment as to the probability of a return of the catastrophe.

In the first place, it must be observed that the occurrence of a great convulsion, away from centres of volcanic activity, and remote from mountains which exhibit recent disturbances, is exceedingly rare. The great alluvial regions—the regions of far-reaching horizontal stratification—have never, save in this single instance, been visited by a great convulsion of this kind, although they occupy quite one half of the earth's surface, or at least of that part which is within the historic belt. No such convulsion, nor any considerable earthquake, had occurred in the hundred and fifty years which had passed since the country came within the observation of travelers. The French explorers would probably have found some accounts of such a catastrophe, in the traditions of the Indians, on whom, as on all rude peoples, such events make a very strong impression. Great earthquakes, like deluges and other destructive natural accidents, become woven in with the traditions of a people, and preserved for centuries. Over three score years have passed, and the trifling shocks which have been felt in this valley have been, one and all, isolated shocks, and had nothing like the serial continuity which belonged to the disturbances of 1811–'13; so that, for hundreds of years before, and for three fifths of a century since this disturbance, there has been nothing like a renewal of the movements. A still better argument for the rarity of this accident in this section is found in the exceedingly extensive disturbances which it caused in the beds bordering on the Mississippi. It is one of the results of a great convulsion of the earth to discharge the tensions near the surface in the region where it occurs. Rocks almost ready to fall, but the fall of which might be distributed over centuries, come down in confusion together. Pent-up gases, which would be slowly discharged, are thrown out at once, and in other ways unstable equilibriums are adjusted. In the region bordering on the Mississippi, a prodigious number of land-slips, crevices in the earth, and sand-blows or outpourings of gas driving sand before it, took place, all tending to show that the tensions which were discharged were very great in number, and probably had not been released for a

very long time by any similar convulsion. Altogether, the evidence looks towards the conclusion that a great disturbance of this kind is quite out of the natural order of events, and may be so exceptional as not to be expected to occur again for any reasonable time in the future.

It is an exceedingly interesting fact that the centre of these oscillations, or seismic vertical, as it is called, seemed to move from the region about New Madrid in an easterly direction, during the continuance of the disturbances. At the end of the series of movements, in 1813, it seems to have been nearly one hundred miles to the east of its position at the beginning of the convulsions. It seems to me that this may have a bearing on the theory of that class of earthquake disturbances when the movements take the form of successive movements occurring in a serial order. I am inclined to believe that they are not produced by the formation of faults, but by the slipping of deep-seated rocks on each other, in the effort to adjust the strains which had developed within them. This gradual eastwardly movement looks like a transfer of the slipping action gradually towards the Cincinnati axis, where the mountain-causing forces have been satisfied by the elevation of a great ridge. I only suggest this conjecture, because it seems to fall in with the theory that these continued tremblings are connected with a slipping movement of deep-seated beds.

It may not be out of place to notice, that the extensive development of very old and very extensive caverns, in the central district of the State, in which there are few indications of any violent actions which cannot be explained without the intervention of earthquakes, is something of an argument on this point, though I doubt if we can determine its precise value. There is a fact, however, in this connection, which may have some value. I have noticed in the Mammoth Cave, Salts Cave, and other caverns in the Edmonson district, that beneath the stones in many avenues we can find a great many bits of charcoal remains of the ancient torches. It is claimed by the guides, that, since the modern extensive visiting of the

Mammoth Cave, the fall of a single stone has not been noticed. The quantities of stone, with chips of charcoal beneath them, requires us to suppose, either that the Indians have been entering these caverns from a time of very great antiquity, or that there has been some convulsion which brought down quantities of stones at one time. There is nothing to show that the earthquake of 1811 may not have done this; but a somewhat careful inquiry among the early settlers has failed to give me any observations on changes made within our caverns by that disturbance. It should be noticed, however, that they were but little entered in those days.*

Before leaving the study of the forces which lead to movements of the earth's crust, I must call the attention of observers to some obscure indications which may, or may not, be connected with changes of level within the State. In the neighborhood of Pine Mountain, on the head waters of the Cumberland, the streams very generally have the character of extremely sluggish, swamp-bordered channels. At every other point observed by me in the Appalachians, the mountain streams have shown a considerable fall, usually not less, for terminal streams, than three or four feet per mile. Yellow Creek, Marshy Creek, and, in fact, about all the smaller tributaries of the Cumberland on the west and south sides, have more or less of this swampy character. We frequently find that, for many miles, the stream will not touch its rock-bed, and is clearly quite incapable, on its present position, of cutting out the valley in which it runs. I have been driven to the hypothesis that, since these valleys were formed, there has been some change of level which has diminished their cutting power.

Marsh Creek, in Wayne county, about 12 miles east of the Cincinnati Southern Railway, and the other creeks having a similar position, would have their peculiarities accounted for by supposing a sinking of the beds on the west side of the

* Although the caverns were somewhat used for making saltpetre, they were little explored by the early settlers until the Mammoth Cave began to be resorted to by travelers from a distance.

Pine Mountain fault, amounting to, say, twenty or thirty feet, the subsidence becoming less and less as we went further and further from the fault. Yellow Creek Valley, which is in the synclinal trough, is not so easily explained. I believe that it is quite incapable of cutting out its valley at the present time. Over a large part of its course it has no wearing action against the sides of the valley; yet, with its feeble stream, it has worked down at least two hundred feet lower than the general surface of the Powell Valley, on the other side of the Cumberland Mountain. The only way in which I can account for this loss of cutting power, is by supposing that the latest movements, which must have been exceedingly near the present time, increased the barrier which separates this stream from the lower waters of the Cumberland, or possibly actually depressed the synclinal so as to make the trough lower than it was before.

It may be said that the movements, necessary to bring about these changes of level, would necessarily have left some more conspicuous mark on the line of the fault than exists at present. I do not attach much importance to this objection, for the amount of movement required is probably not more than fifty feet; and this can be supposed to have occurred without causing any evident disturbance along the line of fault. This line is obscured by a great mass of talus material; and this would effectively hide all the changes which would be brought about by a few feet of movement.

I have been forced to the conclusion that all mountain ranges, where the mountain-building forces are still active, the movements dependent on their continued changes of weight are almost incessant. I can accept no other view than that continents and mountains are, on the whole, in a state of unstable equilibrium. The forces which lifted them having acted to that point where they were just balanced, the weight and the forces that tended to raise up were equal with the forces that tended to bear down. The loss of weight through erosion would naturally be attended by a continued slight movement of re-adjustments, and the increase of strains from the loss of

heat in the crust would likewise be attended by the change of tensions. On this ground of constant slight changes, the peculiar relations of some of these valleys can be well explained.
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APPENDIX A.

The following pages are taken from the admirable work of Hon. Geo. P. Marsh, which is better known by its first name of "Man and Nature," than by the title of the second edition, "The Earth as Modified by Human Action."* The Commonwealth of Kentucky is indebted to the illustrious author for the permission he has given me of making these limited extracts from his extended treatise.

It is my duty to call the attention of the reader to the fact that the following pages, shorn of their context, give a very inadequate idea of the author's treatment of his subject. His treatise is the great masterpiece among the many essays that have been written upon this subject, and should be read by all who desire to understand the effects of man's action on our earth's history:

Extracts from the Earth as Modified by Human Action, by George P. Marsh.

"INUNDATIONS IN WINTER.

"In the Northern United States, although inundations are not very unfrequently produced by heavy rains in the height of summer, it will be found generally true that the most rapid rise of the waters, and, of course, the most destructive 'freshets,' as they are called in America, are occasioned by the sudden dissolution of the snow before the open ground is thawed in the spring. It frequently happens that a powerful thaw sets in after a long period of frost, and the snow which had been months in accumulating is dissolved and carried off in a few hours. When the snow is deep, it, to use a popular expression, 'takes the frost out of the ground' in the woods, and, if it lies long enough, in the fields also. But the heaviest snows usually fall after midwinter, and are succeeded by warm

*The Earth as Modified by Human Action, a new edition of Man and Nature, by George P. Marsh: New York, Scribner, Armstrong & Co., 1874.

rains or sunshine, which dissolve the snow on the cleared land before it has had time to act upon the frost-bound soil beneath it. In this case, the snow in the woods is absorbed as fast as it melts, by the soil it has protected from freezing, and does not materially contribute to swell the current of the rivers. If the mild weather, in which great snow-storms usually occur, does not continue and become a regular thaw, it is almost sure to be followed by drifting winds, and the inequality with which they distribute the snow over the cleared ground leaves the ridges of the surface-soil comparatively bare, while the depressions are often filled with drifts to the height of many feet. The knolls become frozen to a great depth; succeeding partial thaws melt the surface-snow, and the water runs down into the furrows of ploughed fields, and other artificial and natural hollows, and then often freezes to solid ice. In this state of things, almost the entire surface of the cleared land is impervious to water, and from the absence of trees and the general smoothness of the ground, it offers little mechanical resistance to superficial currents. If, under these circumstances, warm weather accompanied by rain occurs, the rain and melted snow are swiftly hurried to the bottom of the valleys and gathered to raging torrents.

"It ought further to be considered that, though the lighter ploughed soils readily imbibe a great deal of water, yet grass-lands, and all the heavy and tenacious earths, absorb it in much smaller quantities, and less rapidly than the vegetable mould of the forest. Pasture, meadow, and clayey soils, taken together, greatly predominate over sandy ploughed fields, in all large agricultural districts, and hence, even if, in the case we are supposing, the open ground chance to have been thawed before the melting of the snow which covers it, it is already saturated with moisture, or very soon becomes so, and, of course, cannot relieve the pressure by absorbing more water. The consequence is, that the face of the country is suddenly flooded with a quantity of melted snow and rain equivalent to a fall of six or eight inches of the latter, or even more. This runs unobstructed to rivers often still-bound will thick ice, and

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thus inundations of a fearfully devastating character are produced. The ice bursts, from the hydrostatic pressure from below, or is violently torn up by the current, and is swept by the impetuous stream, in large masses and with resistless fury, against banks, bridges, dams, and mills erected near them. The bark of the trees along the rivers is often abraded, at a height of many feet above the ordinary water-level, by cakes of floating ice, which are at last stranded by the receding flood on meadow or ploughland, to delay, by their chilling influence, the advent of the tardy spring.

"Another important effect of the removal of the forest shelter in cold climates may be noticed here. We have observed that the ground in the woods either does not freeze at all, or that if frozen it is thawed by the first considerable snow-fall. On the contrary, the open ground is usually frozen when the first spring freshet occurs, but is soon thawed by the warm rain and melting snow. Nothing more effectually disintegrates a cohesive soil than freezing and thawing, and the surface of earth which has just undergone those processes is more subject to erosion by running water than under any other circumstances. Hence more vegetable mould is washed away from cultivated grounds in such climates by the spring floods than by the heaviest rain at other seasons.

"In the warm climates of Southern Europe, as I have already said, the functions of the forest, so far as the disposal of the water of precipitation is concerned, are essentially the same at all seasons, and are analogous to those which it performs in the Northern United States in summer. Hence, in the former countries, the winter floods have not the characteristics which mark them in the latter, nor is the conservative influence of the woods in winter relatively so important, though it is equally unquestionable.

"If the summer floods in the United States are attended with less pecuniary damage than those of the Loire and other rivers of France, the Po and its tributaries in Italy, the Emme and her sister torrents which devastate the valleys of Switzerland, it is partly because the banks of American rivers are not

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yet lined with towns, their shores and the bottoms which skirt them not yet covered with improvements whose cost is counted by millions, and, consequently, a smaller amount of property is exposed to injury by inundation. But the comparative exemption of the American people from the terrible calamities which the overflow of rivers has brought on some of the fairest portions of the Old World, is, in a still greater degree, to be ascribed to the fact that, with all our thoughtless improvidence, we have not yet bared all the sources of our streams, not yet overthrown all the barriers which nature has erected to restrain her own destructive energies. Let us be wise in time, and profit by the errors of our older brethren!

"The influence of the forest in preventing inundations has been very generally recognized, both as a theoretical inference and as a fact of observation; but the eminent engineer Belgrand, and his commentator Vallès, have deduced an opposite result from various facts of experience and from scientific considerations. They contend that the superficial drainage is more regular from cleared than from wooded ground, and that clearing diminishes rather than augments the intensity of inundations. Neither of these conclusions appears to be warranted by their data or their reasoning, and they rest partly upon facts, which, truly interpreted, are not inconsistent with the received opinions on these subjects, partly upon assumptions which are contradicted by experience. Two of these latter are, first, that the fallen leaves in the forest constitute an impermeable covering of the soil over, not through, which the water of rains and of melting snows flows off, and secondly, that the roots of trees penetrate and choke up the fissures in the rocks, so as to impede the passage of water through channels which nature has provided for its descent to lower strata.

"As to the first of these, we may appeal to familiar facts within the personal knowledge of every man acquainted with the operations of sylvan nature. Rain-water never, except in very trifling quantities, flows over the leaves in the woods in summer or autumn. Water runs over them only in the spring, in the rare cases when they have been pressed down smoothly

and compactly by the weight of the snow—a state in which they remain only until they are dry, when shrinkage and the action of the wind soon roughen the surface so as effectually to stop, by absorption, all flow of water. I have observed that when a sudden frost succeeds a thaw at the close of the winter, after the snow has principally disappeared, the water in and between the layers of leaves sometimes freezes into a solid crust, which allows the flow of water over it. But this occurs only in depressions and on a very small scale; and the ice thus formed is so soon dissolved that no sensible effect is produced on the escape of water from the general surface.

"As to the influence of roots upon drainage, we have seen that there is no doubt that they, independently of their action as absorbents, mechanically promote it. Not only does the water of the soil follow them downwards, but their swelling growth powerfully tends to enlarge, not to obstruct, the crevices of rock into which they enter; and as the fissures in rocks are longitudinal, not mere circular orifices, every line of additional width gained by the growth of roots within them increases the area of the crevice in proportion to its length. Consequently, the widening of a fissure to the extent of one inch might give an additional drainage equal to a square foot of open tubing.

"The observations and reasonings of Belgrand and Vallès, though their conclusions have not been accepted by many, are very important in one point of view. These writers insist much on the necessity of taking into account, in estimating the relations between precipitation and evaporation, the abstraction of water from the surface and surface-currents, by absorption and infiltration—an element unquestionably of great value, but hitherto much neglected by meteorological inquirers, who have very often reasoned as if the surface-earth were either impermeable to water or already saturated with it; whereas, in fact, it is a sponge, always imbibing humidity and always giving it off, not by evaporation only, but by infiltration and percolation.

"The remarkable historical notices of inundations in France in the Middle Ages collected by Champion* are considered by many as furnishing proof that when that country was much more generally covered with wood than it now is, destructive inundations of the French rivers were not less frequent than they are in modern days. But this evidence is subject to this among other objections: we know, it is true, that the forests of certain departments of France were anciently much more extensive than at the present day; but we know also that in many portions of that country the soil has been bared of its forests, and then, in consequence of the depopulation of great provinces, left to reclothe itself spontaneously with trees, many times during the historic period; and our acquaintance with the forest topography of ancient Gaul or of mediæval France is neither sufficiently extensive nor sufficiently minute to permit us to say, with certainty, that the sources of this or that particular river were more or less sheltered by wood at any given time, ancient or mediæval, than at present.† I say the sources of the rivers, because the floods of great rivers are occasioned by heavy rains and snows which fall in the more elevated regions around the primal springs, and not by precipitation in the main valleys or on the plains bordering on the lower course.

"The destructive effects of inundations, considered simply as a mechanical power by which life is endangered, crops destroyed, and the artificial constructions of man overthrown, are very terrible. Thus far, however, the flood is a temporary and by no means an irreparable evil, for if its ravages end here, the prolific powers of nature and the industry of man soon restore what had been lost, and the face of the earth no longer shows traces of the deluge that had overwhelmed it.

*"*Les Inondations en France depuis le VIe siècle jusqu'à nos jours.* 6 vols. 8vo. Paris, 1858–'64. See a very able review of this learned and important work by Prof. Messedaglia, read before the Academy of Agriculture at Verona in 1864."

†"Alfred Maury has, nevertheless, collected, in his erudite and able work *Les Forêts de la Gaule et de l'ancienne France*, Paris, 1867, an immense amount of statistical detail on the extent, the distribution, and the destruction of the forests of France, but it still remains true that we can very seldom pronounce on the forestal condition of the upper valley of a particular river at the time of a given inundation in the ancient or the mediæval period."

Inundations have even their compensations. The structures they destroy are replaced by better and more secure erections; and if they sweep off a crop of corn, they not unfrequently leave behind them, as they subside, a fertilizing deposit which enriches the exhausted field for a succession of seasons.* If, then, the too rapid flow of the surface-waters occasioned no other evil than to produce, once in ten years upon the average, an inundation which should destroy the harvest of the low grounds along the rivers, the damage would be too inconsiderable, and of too transitory a character, to warrant the inconveniences and the expense involved in the measures which the most competent judges in many parts of Europe believe the respective governments ought to take to obviate it.

"DESTRUCTIVE ACTION OF TORRENTS.

"But the great, the irreparable, the appalling mischiefs which have already resulted, and which threaten to ensue on a still more extensive scale hereafter, from too rapid superficial drainage, are of a properly geographical, we may almost say geological, character, and consist primarily in erosion, dis-

*"The productiveness of Egypt has been attributed too exclusively to the fertilizing effects of the slime deposited by the inundations of the Nile; for in that climate a liberal supply of water would produce good crops on almost any ordinary sand, while, without water, the richest soil would yield nothing. The sediment deposited annually is but a very small fraction of an inch in thickness. It is alleged that in quantity it would be hardly sufficient for a good top-dressing, and that in quality it is not chemically distinguishable from the soil inches or feet below the surface. But to deny, as some writers have done, that the slime has any fertilizing properties at all, is as great an error as the opposite one of ascribing all the agricultural wealth of Egypt to that single cause of productiveness. Fine soils deposited by water are almost uniformly rich in all climates; those brought down by rivers, carried out into salt-water, and then returned again by the tide, seem to be more permanently fertile than any others. The polders of the Netherland coast are of this character, and the meadows in Lincolnshire, which have been covered with slime by *warping*, as it is called, or admitting water over them at high tide, are remarkably productive.

"Recent analysis is said to have detected in the water of the Nile a quantity of organic matter—derived mainly, no doubt, from the decayed vegetation it bears down from its tropical course—sufficiently large to furnish an important supply of fertilizing ingredients to the soil.

"It is computed that the Durance—a river fed chiefly by torrents of great erosive power —carries down annually solid material enough to cover 272,000 acres of soil with a deposit of two fifths of an inch in thickness, and that this deposit contains, in the combination most favorable to vegetation, more azote than 110,000 tons of guano, and more carbon than 121,000 acres of woodland would assimilate in a year. Elisée Reclus, *La Terre*, vol. I, p. 467. On the chemical composition, quantity, and value of the solid matter transported by river, see Hervé Mangon, *Sur l'Emploi des Eaux dans les Irrigations*, 8vo. Paris, 1869, pp. 132 *et seq.* Duponchel, *Traité d'Hydraulique et de Géologie Agricoles.* Paris, 1868, chap. I, XII, and XIII."

placement, and transportation of the superficial strata, vegetable and mineral—of the integuments—so to speak, with which nature has clothed the skeleton frame-work of the globe. It is difficult to convey by description an idea of the desolation of the regions most exposed to the ravages of torrent and of flood; and the thousands who, in these days of swift travel, are whirled by steam near or even through the theatres of these calamities, have but rare and imperfect opportunities of observing the destructive causes in action. Still more rarely can they compare the past with the actual condition of the provinces in question, and trace the progress of their conversion from forest-crowned hills, luxuriant pasture grounds, and abundant cornfields and vineyards well watered by springs and fertilizing rivulets, to bald mountain ridges, rocky declivities, and steep earth-banks furrowed by deep ravines with beds now dry, now filled by torrents of fluid mud and gravel hurrying down to spread themselves over the plain, and dooming to everlasting barrenness the once productive fields. In surveying such scenes, it is difficult to resist the impression that nature pronounced a primal curse of perpetual sterility and desolation upon these sublime but fearful wastes, difficult to believe that they were once, and but for the folly of man might still be, blessed with all the natural advantages which Providence has bestowed upon the most favored climes. But the historical evidence is conclusive as to the destructive changes occasioned by the agency of man upon the flanks of the Alps, the Apennines, the Pyrenees, and other mountain ranges in Central and Southern Europe, and the progress of physical deterioration has been so rapid that, in some localities, a single generation has witnessed the beginning and the end of the melancholy revolution.

"I have stated, in a general way, the nature of the evils in question, and of the processes by which they are produced; but I shall make their precise character and magnitude better understood by presenting some descriptive and statistical details of facts of actual occurrence. I select for this purpose the southeastern portion of France, not because that territory

has suffered more severely than some others, but because its deterioration is comparatively recent, and has been watched and described by very competent and trustworthy observers, whose reports are more easily accessible than those published in other countries.*

"The provinces of Dauphiny and Provence comprise a territory of fourteen or fifteen thousand square miles, bounded northwest by the Isere, northeast and east by the Alps, south by the Mediterranean, west by the Rhone, and extending from 42° to about 45° of north latitude. The surface is generally hilly and even mountainous, and several of the peaks in Dauphiny rise above the limit of perpetual snow. Except upon the mountain ridges, the climate, as compared with that of the United States in the same latitude, is extremely mild. Little snow falls, except upon the higher mountains, the frosts are light, and the summers long, as might, indeed, be inferred from the vegetation; for in the cultivated districts, the vine and the fig everywhere flourish; the olive thrives as far north as 43½°, and upon the coast grow the orange, the lemon, and the date-palm. The forest trees, too, are of southern type, umbrella pines, various species of evergreen oaks, and many other trees and shrubs of persistent broad-leaved foliage, characterizing the landscape.

"The rapid slope of the mountains naturally exposed these provinces to damage by torrents, and the Romans diminished their injurious effects by erecting, in the beds of ravines, barriers of rocks loosely piled up, which permitted a slow escape of the water, but compelled it to deposit above the dikes the earth and gravel with which it was charged.† At a later

* "Streffleur (*Ueber die Natur und die Wirkungen der Wildbäche*, p. 3) maintains that all the observations and speculations of French authors on the nature of torrents had been anticipated by Austrian writers. In proof of this assertion he refers to the works of Franz von Zallinger, 1778, Von Arretin, 1808, Franz Duile, 1826, all published at Innsbruck, and Hagen's *Beschreibung neuerer Wasserbauwerke* Königsberg, 1826, none of which works are known to me. It is evident, however, that the conclusions of Surell and other French writers whom I cite, are original results of personal investigation, and not borrowed opinions."

† "Whether Palissy was acquainted with this ancient practice, or whether it was one of those original suggestions of which his works are so full, I know not, but in his treatise, *Des Eaux et Fontaines*, he thus recommends it, by way of reply to the objections of 'Théorique,' who had expressed the fear that 'the waters which rush violently down

period the Crusaders brought home from Palestine, with much other knowledge gathered from the wiser Moslems, the art of securing the hillsides and making them productive by terracing and irrigation. The forests which covered the mountains secured an abundant flow of springs, and the process of clearing the soil went on so slowly that, for centuries, neither the want of timber and fuel, nor the other evils about to be depicted, were seriously felt. Indeed, throughout the Middle Ages, these provinces were well wooded, and famous for the fertility and abundance, not only of the low grounds, but of the hills.

"Such was the state of things at the close of the fifteenth century. The statistics of the seventeenth show that while there had been an increase of prosperity and population in Lower Provence, as well as in the correspondingly situated parts of the other two provinces I have mentioned, there was an alarming decrease both in the wealth and in the population of Upper Provence and Dauphiny, although, by the clearing of the forests, a great extent of plough-land and pasturage had been added to the soil before reduced to cultivation. It was found, in fact, that the augmented violence of the torrents had swept away, or buried in sand and gravel, more land than had been reclaimed by clearing; and the taxes computed by fires or habitations underwent several successive reductions in consequence of the gradual abandonment of the wasted soil by its starving occupants. The growth of the large towns on and near the Rhone and the coast, their advance in commerce and industry, and the consequently enlarged demand for agricultural products, ought naturally to have increased the rural population and the value of their lands; but the physical decay of the uplands was such that considerable tracts were deserted altogether, and in Upper Provence, the fires which in 1471

from the heights of the mountain would bring with them much earth, sand, and other things,' and thus spoil the artificial fountain that 'Practique' was teaching him to make: 'And for hindrance of the mischiefs of great waters which may be gathered in few hours by great storms, when thou shalt have made ready thy parterre to receive the water, thou must lay great stones athwart the deep channels which lead to thy parterre. And so the force of the rushing currents shall be deadened, and thy water shall flow peacefully into his cisterns.'—*Œuvres Complètes*, p. 173."

counted 897, were reduced to 747 in 1699, to 728 in 1733, and to 635 in 1776.*

"Surell—whose admirable work, *Étude sur les Torrents des Hautes Alpes*, first published in 1841,† presents a most appalling picture of the desolations of the torrent, and, at the same time, the most careful studies of the history and essential character of this great evil—in speaking of the valley of Dévoluy, on page 152, says: 'Everything concurs to show that it was anciently wooded. In its peat-bogs are found buried trunks of trees, monuments of its former vegetation. In the frame-work of old houses, one sees enormous timber, which is no longer to be found in the district. Many localities, now completely bare, still retain the name of "wood," and one of them is called, in old deeds, *Comba nigra* [Black forest or dell], on account of its dense woods. These and many other proofs confirm the local traditions which are unanimous on this point.

"'There, as everywhere in the Upper Alps, the clearings began on the flanks of the mountains, and were gradually extended into the valleys and then to the highest accessible peaks. Then followed the Revolution, and caused the destruction of the remainder of the trees which had thus far escaped the woodman's axe.'

"In a note to this passage the writer says: 'Several persons have told me that they had lost flocks of sheep, by straying, in the forests of Mont Auroux, which covered the flanks of the mountain from La Cluse to Agnères. These declivities are now as bare as the palm of the hand.'

"The ground upon the steep mountains being once bared of trees, and the underwood killed by the grazing of horned cattle, sheep, and goats, every depression becomes a watercourse. 'Every storm,' says Surell, page 153, 'gives rise to a

*"These facts I take from the *La Provence au point de vue des Bois, des Torrents et des nondations*, of Charles de Ribbe, one of the highest authorities."

†"A second edition of this work, with an additional volume of great value by Ernest Cézanne, was published at Paris, in two 8vo volumes, in 1871–'72."

new torrent.* Examples of such are shown, which, though not yet three years old, have laid waste the finest fields of their valleys, and whole villages have narrowly escaped being swept into ravines formed in the course of a few hours. Sometimes the flood pours in a sheet over the surface, without ravine or even bed, and ruins extensive grounds, which are abandoned forever.'

"I cannot follow Surell in his description and classification of torrents, and I must refer the reader to his instructive work for a full exposition of the theory of the subject. In order, however, to show what a concentration of destructive energies may be effected by felling the woods that clothe and support the sides of mountain abysses, I cite his description of a valley descending from the Col Isoard, which he calls 'a complete type of a basin of reception,' that is, a gorge which serves as a common point of accumulation and discharge for the waters of several lateral torrents. 'The aspect of the monstrous channel,' says he, 'is frightful. Within a distance of less than two English miles, more than sixty torrents hurl into the depths of the gorge the débris torn from its two flanks. The smallest of these secondary torrents, if transferred to a fertile valley, would be enough to ruin it.'

"The eminent political economist Blanqui, in a memoir read before the Academy of Moral and Political Science on the 25th of November, 1843, thus expresses himself: 'Important as are the causes of impoverishment already described, they are not to be compared to the consequences which have followed from the two inveterate evils of the Alpine provinces of France, the extension of clearing and the ravages of torrents. . . . The most important result of this destruction is this: that the agricultural capital, or rather the ground itself—which, in a rapidly increasing degree, is daily swept away by

*"No attentive observer can frequent the southern flank of the Piedmontese Alps or the French province of Dauphiny, for half a dozen years, without witnessing with his own eyes the formation and increase of new torrents. I can bear personal testimony to the conversion of more than one grassy slope into the bed of a furious torrent by baring the hills above of their woods."

the waters—is totally lost. Signs of unparalleled destitution are visible in all the mountain zone, and the solitudes of those districts are assuming an indescribable character of sterility and desolation. The gradual destruction of the woods has, in a thousand localities, annihilated at once the springs and the fuel. Between Grenoble and Briançon, in the valley of the Romanche, many villages are so destitute of wood that they are reduced to the necessity of baking their bread with sun-dried cow-dung, and even this they can afford to do but once a year.

"'Whoever has visited the valley of Barcelonette, those of Embrun, and of Verdun, and that Arabia Petræa of the department of the Upper Alps, called Dévoluy, knows that there is no time to lose—that in fifty years from this date France will be separated from Savoy, as Egypt from Syria, by a desert.'*

"It deserves to be specially noticed that the district here referred to, though now among the most hopelessly waste in France, was very productive even down to so late a period as the commencement of the French Revolution. Arthur Young, writing in 1789, says: 'About Barcelonette and in the highest parts of the mountains, the hill-pastures feed a million of sheep, besides large herds of other cattle;' and he adds: 'With such a soil and in such a climate, we are not to suppose a country barren because it is mountainous. The valleys I have visited are, in general, beautiful.'† He ascribes the same character to the provinces of Dauphiny, Provence, and Auvergne, and, though he visited, with the eye of an attentive and practiced observer, many of the scenes since blasted with the wild desolation described by Blanqui, the Durance and a part of the course of the Loire are the only streams he

*"Ladoucette says the peasant of Dévoluy 'often goes a distance of five hours over rocks and precipices for a single [man's] load of wood;' and he remarks on another page, that 'the justice of peace of that canton had, in the course of forty-three years, but once heard the voice of the nightingale.'—*Histoire, etc., des Hautes Alpes*, pp. 220, 434."

†"The valley of Embrun, now almost completely devastated, was once remarkable for its fertility. In 1806, Héricart de Thury said of it: 'In this magnificent valley nature had been prodigal of her gifts. Its inhabitants have blindly reveled in her favors, and fallen asleep in the midst of her profusion.'—Becquerel, *Des Climats*, etc., p. 314."

mentions as inflicting serious injury by their floods. The ravages of the torrents had, indeed, as we have seen, commenced earlier in some other localities, but we are authorized to infer that they were, in Young's time, too limited in range, and relatively too insignificant, to require notice in a general view of the provinces where they have now ruined so large a proportion of the soil.

"But I resume my citations.

"'I do not exaggerate,' says Blanqui. 'When I shall have finished my description and designated localities by their names, there will rise, I am sure, more than one voice from the spots themselves, to attest the rigorous exactness of this picture of their wretchedness. I have never seen its equal even in the Kabyle villages of the province of Constantine; for there you can travel on horseback, and you find grass in the spring, whereas in more than fifty communes in the Alps there is absolutely nothing.

"'The clear, brilliant, Alpine sky of Embrun, of Gap, of Barcelonette, and of Digne, which for months is without a cloud, produces droughts interrupted only by diluvial rains like those of the tropics. The abuse of the right of pasturage and the felling of the woods have stripped the soil of all its grass and all its trees, and the scorching sun bakes it to the consistence of porphyry. When moistened by the rain, as it has neither support nor cohesion, it rolls down to the valleys, sometimes in floods resembling black, yellow, or reddish lava, sometimes in streams of pebbles, and even huge blocks of stone, which pour down with a frightful roar, and in their swift course exhibit the most convulsive movements. If you overlook from an eminence one of these landscapes furrowed with so many ravines, it presents only images of desolation and of death. Vast deposits of flinty pebbles, many feet in thickness, which have rolled down and spread far over the plain, surround large trees, bury even their tops, and rise above them, leaving to the husbandman no longer a ray of hope. One can imagine no sadder spectacle than the deep fissures in the flanks of the mountains, which seem to have

burst forth in eruption to cover the plains with their ruins. These gorges, under the influence of the sun which cracks and shivers to fragments the very rocks, and of the rain which sweeps them down, penetrate deeper and deeper into the heart of the mountain, while the beds of the torrents issuing from them are sometimes raised several feet in a single year, by the débris, so that they reach the level of the bridges, which, of course, are then carried off. The torrent-beds are recognized at a great distance, as they issue from the mountains, and they spread themselves over the low grounds, in fan-shaped expansions, like a mantle of stone, sometimes ten thousand feet wide, rising high at the centre, and curving toward the circumference till their lower edges meet the plain.

"'Such is their aspect in dry weather. But no tongue can give an adequate description of their devastations in one of those sudden floods which resemble, in almost none of their phenomena, the action of ordinary river-water. They are now no longer overflowing brooks, but real seas, tumbling down in cataracts, and rolling before them blocks of stone, which are hurled forwards by the shock of the waves like balls shot out by the explosion of gunpowder. Sometimes ridges of pebbles are driven down when the transporting torrent does not rise high enough to show itself, and then the movement is accompanied with a roar louder than the crash of thunder. A furious wind precedes the rushing water and announces its approach. Then comes a violent eruption, followed by a flow of muddy waves, and after a few hours all returns to the dreary silence which at periods of rest marks these abodes of desolation.*

*"These explosive gushes of mud and rock appear to be occasioned by the caving in of large masses of earth from the banks of the torrent, which dam up the stream and check its flow until it has acquired volume enough to burst the barrier and carry all before it. In 1827, such a sudden eruption of a torrent, after the current had appeared to have ceased, swept off forty-two houses and drowned twenty-eight persons in the village of Goncelin, near Grenoble, and buried with rubbish a great part of the remainder of the village.

"The French traveler, D'Abbadie, relates precisely similar occurrences as not unfrequent in the mountains of Abyssinia.—Surell, *Études, etc.*, 2d edition, pp. 224, 295."

"'The elements of destruction are increasing in violence. The devastation advances in geometrical progression as the higher slopes are bared of their wood, and "the ruin from above," to use the words of a peasant, "helps to hasten the desolation below."

"'The Alps of Provence present a terrible aspect. In the more equable climate of Northern France, one can form no conception of those parched mountain gorges where not even a bush can be found to shelter a bird, where, at most, the wanderer sees in summer here and there a withered lavender, where all the springs are dried up, and where a dead silence, hardly broken by even the hum of an insect, prevails. But if a storm bursts forth, masses of water suddenly shoot from the mountain heights into the shattered gulfs, waste without irrigating, deluge without refreshing the soil they overflow in their swift descent, and leave it even more seared than it was from want of moisture. Man at last retires from the fearful desert, and I have, the present season, found not a living soul in districts where I remember to have enjoyed hospitality thirty years ago.'

"In 1853, ten years after the date of Blanqui's memoir, M. de Bonville, prefect of the lower Alps, addressed to the government a report in which the following passages occur:

"'It is certain that the productive mould of the Alps, swept off by the increasing violence of that curse of the mountains, the torrents, is daily diminishing with fearful rapidity. All our Alps are wholly, or in large proportion, bared of wood. Their soil, scorched by the sun of Provence, cut up by the hoofs of the sheep, which, not finding on the surface the grass they require for their sustenance, gnaw and scratch the ground in search of roots to satisfy their hunger, is periodically washed and carried off by melting snows and summer storms.

"'I will not dwell on the effects of the torrents. For sixty years they have been too often depicted to require to be further discussed, but it is important to show that their ravages are daily extending the range of devastation. The bed of

the Durance, which now in some places exceeds a mile and a quarter in width, and, at ordinary times, has a current of water less than eleven yards wide, shows something of the extent of the damage.* Where, ten years ago, there were still woods and cultivated grounds to be seen, there is now but a vast torrent; there is not one of our mountains which has not at least one torrent, and new ones are daily forming.

"'An indirect proof of the diminution of the soil is to be found in the depopulation of the country. In 1852 I reported to the General Council that, according to the census of that year, the population of the department of the Lower Alps had fallen off no less than 5,000 souls in the five years between 1846 and 1851.

"'Unless prompt and energetic measures are taken, it is easy to fix the epoch when the French Alps will be but a desert. The interval between 1851 and 1856 will show a further decrease of population. In 1862 the ministry will announce a continued and progressive reduction in the number of acres devoted to agriculture; every year will aggravate the evil, and in half a century France will count more ruins, and a department the less.'

"Time has verified the predictions of De Bonville. The later census returns show a progressive diminution in the population of the departments of the Lower Alps, the Isère, Drome, Ariège, the Upper and the Lower Pyrenees, Lozère, and Ardennes, Doubs, the Vosges, and, in short, in all the provinces formerly remarkable for their forests. This diminution is not to be ascribed to a passion for foreign emigration, as in Ireland, and in parts of Germany and of Italy; it is simply a transfer of population from one part of the empire to another, from soils which human folly has rendered uninhabitable, by ruthlessly depriving them of their natural advantages and securities, to provinces where the face of the

* "In the days of the Roman Empire the Durance was a navigable, or at least a boatable, river, with a commerce so important that the boatmen upon it formed a distinct corporation.—Ladoucette, *Historie, etc., des Hautes Alpes*, p. 354.

"Even as early as 1789 the Durance was computed to have already covered with gravel and pebbles not less than 130,000 acres, 'which, but for its inundations, would have been the finest land in the province.'—Arthur Young, *Travels in France*, vol. I, ch. I."

earth was so formed by nature as to need no such safeguards, and where, consequently, she preserves her outlines in spite of the wasteful improvidence of man.*

"GENERAL FUNCTIONS OF FORESTS.

"In the preceding pages we have seen that the electrical and chemical action of the forest, though obscure, exercises probably a beneficial, certainly not an injurious, influence on the composition and condition of the atmosphere; that it serves as a protection against the diffusion of miasmatic exhalations and malarious poisons; that it performs a most important function as a mechanical shelter from blasting winds to grounds and crops in the lee of it; that, as a conductor of heat, it tends to equalize the temperature of the earth and the air; that its dead products form a mantle over the surface, which protects the earth from excessive heat and cold; that the evaporation from the leaves of living trees, while it cools the air around them, diffuses through the atmosphere a medium which resists the escape of warmth from the earth by radiation, and hence that its general effect is to equilibrate caloric influences and moderate extremes of temperature.

"We have seen, further, that the forest is equally useful as a regulator of terrestrial and of atmospheric humidity, preventing by its shade the drying up of the surface by parching winds and the scorching rays of the sun, intercepting a part of the precipitation, and pouring out a vast quantity of aqueous vapor into the atmosphere; that if it does not increase the amount of rain, it tends to equalize its distribution both in time and in place; that it preserves a hygrometric equilibrium in the superior strata of the earth's surface; that it maintains and regulates the flow of springs and rivulets; that it checks

* "Between 1851 and 1856 the population of Languedoc and Provence had increased by 101,000 souls. The augmentation, however, was wholly in the provinces of the plains, where all the principal cities are found. In these provinces the increase was 204,000, while in the mountain provinces there was a diminution of 103,000. The reduction of the area of arable land is perhaps even more striking. In 1842 the department of the Lower Alps possessed 99,000 hectares, or nearly 245,000 acres, of cultivated soil. In 1852 it had but 74,000 hectares. In other words, in ten years 25,000 hectares, or 61,000 acres, had been washed away, or rendered worthless for cultivation, by torrents and the abuses of pasturage.—Clavé, *Études*, pp. 66, 67."

the superficial discharge of the waters of precipitation, and consequently tends to prevent the sudden rise of rivers, the violence of floods, the formation of destructive torrents, and the abrasion of the surface by the action of running water; that it impedes the fall of avalanches and of rocks, and destructive slides of the superficial strata of mountains; that it is a safeguard against the breeding of locusts, and finally that it furnishes nutriment and shelter to many tribes of animal and of vegetable life which, if not necessary to man's existence, are conducive to his rational enjoyment. In fine, in well-wooded regions, and in inhabited countries where a due proportion of soil is devoted to the growth of judiciously distributed forests, natural destructive tendencies of all sorts are arrested or compensated, and man, bird, beast, fish, and vegetable alike find a constant uniformity of condition most favorable to the regular and harmonious coexistence of them all.

"GENERAL CONSEQUENCES OF THE DESTRUCTION OF THE FOREST.

"With the extirpation of the forest, all is changed. At one season, the earth parts with its warmth by radiation to an open sky—receives, at another, an immoderate heat from the unobstructed rays of the sun. Hence the climate becomes excessive, and the soil is alternately parched by the fervors of summer, and seared by the rigors of winter. Bleak winds sweep unresisted over its surface, drift away the snow that sheltered it from the frost, and dry up its scanty moisture. The precipitation becomes as irregular as the temperature; the melting snows and vernal rains, no longer absorbed by a loose and bibulous vegetable mould, rush over the frozen surface, and pour down the valleys seawards, instead of filling a retentive bed of absorbent earth, and storing up a supply of moisture to feed perennial springs. The soil is bared of its covering of leaves, broken and loosened by the plough, deprived of the fibrous rootlets which held it together, dried and pulverized by sun and wind, and at last exhausted by new combinations. The face of the earth is no longer a sponge, but a dust-heap, and the floods which the waters of the sky pour

over it hurry swiftly along its slopes, carrying in suspension vast quantities of earthy particles which increase the abrading power and mechanical force of the current, and, augmented by the sand and gravel of falling banks, fill the beds of the streams, divert them into new channels, and obstruct their outlets. The rivulets, wanting their former regularity of supply and deprived of the protecting shade of the woods, are heated, evaporated, and thus reduced in their summer currents, but swollen to raging torrents in autumn and in spring. From these causes, there is a constant degradation of the uplands, and a consequent elevation of the beds of watercourses and of lakes by the deposition of the mineral and vegetable matter carried down by the waters. The channels of great rivers become unnavigable, their estuaries are choked up, and harbors which once sheltered large navies are shoaled by dangerous sand-bars. The earth, stripped of its vegetable glebe, grows less and less productive, and, consequently, less able to protect itself by weaving a new network of roots to bind its particles together, a new carpeting of turf to shield it from wind and sun and scouring rain. Gradually it becomes altogether barren. The washing of the soil from the mountains leaves bare ridges of sterile rock, and the rich organic mould which covered them, now swept down into the dank low grounds, promotes a luxuriance of aquatic vegetation that breeds fever, and more insidious forms of mortal disease, by its decay, and thus the earth is rendered no longer fit for the habitation of man.*

"To the general truth of this sad picture there are many exceptions, even in countries of excessive climates. Some of these are due to favorable conditions of surface, of geological structure, and of the distribution of rain; in many others, the evil consequences of man's improvidence have not yet been

* "Almost every narrative of travel in those countries which were the earliest seats of civilization, contains evidence of the truth of these general statements, and this evidence is presented with more or less detail in most of the special works on the forest which I have occasion to cite. I may refer particularly to Hohenstein, *Der Wald*, 1860, as full of important facts on this subject. See also Caimi, *Cenni sulla Importanza dei Boschi*, for some statistics, not readily found elsewhere, on this and other topics connected with the forest."

experienced, only because a sufficient time has not elapsed, since the felling of the forest, to allow them to develop themselves. But the vengeance of nature for the violation of her harmonies, though slow, is sure, and the gradual deterioration of soil and climate in such exceptional regions is as certain to result from the destruction of the woods as is any natural effect to follow its cause.

"DUE PROPORTION OF WOODLAND.

"The proportion of woodland that ought to be permanently maintained for its geographical and atmospheric influences varies according to the character of soil, surface, and climate. In countries with a humid sky, or moderately undulating surface and an equable temperature, a small extent of forest, enough to serve as a mechanical screen against the action of the wind in localities where such protection is needed, suffices. But most of the territory occupied by civilized man is exposed, by the character of its surface and its climate, to a physical degradation which cannot be averted except by devoting a large amount of soil to the growth of the woods.

"From an economical point of view, the question of the due proportion of forest is not less complicated or less important than in its purely physical aspects. Of all the raw materials which nature supplies for elaboration by human art, wood is undoubtedly the most useful, and at the same time the most indispensable to social progress.*

* "In an imaginary dialogue in the *Recepte Véritable*, the author, Palissy, having expressed his indignation at the folly of men in destroying the woods, his interlocutor defends the policy of felling them, by citing the example of 'divers bishops, cardinals, priors, abbots, monkeries, and chapters, which, by cutting their woods, have made three profits,' the sale of the timber, the rent of the ground, and the 'good portion' they received of the grain grown by the peasants upon it. To this argument Palissy replies: 'I cannot enough detest this thing, and I call it not an error, but a curse and a calamity to all France; for when forests shall be cut, all arts shall cease, and they which practice them shall be driven out to eat grass with Nebuchadnezzar and the beasts of the field. I have divers times thought to set down in writing the arts which shall perish when there shall be no more wood; but when I had written down a great number, I did perceive that there could be no end of my writing, and having diligently considered, I found there was not any which could be followed without wood.' . . 'And truly I could well allege to thee a thousand reasons, but 'tis so cheap a philosophy, that the very chamber-wenches, if they do but think, may see that without wood, it is not possible to exercise any manner of human art or cunning.'—*Œuvres de* Bernard Palissy. Paris, 1844, p. 89."

"The demand for wood, and of course the quantity of forest required to furnish it, depend upon the supply of fuel from other sources, such as peat and coal, upon the extent to which stone, brick, or metal can advantageously be substituted for wood in building, upon the development of arts and industries employing wood and other forest products as materials, and upon the cost of obtaining them from other countries, or upon their commercial value as articles of export.

"Upon the whole, taking civilized Europe and America together, it is probable that from twenty to twenty-five per cent. of well-wooded surface is indispensable for the maintenance of normal physical conditions, and for the supply of materials so essential to every branch of human industry and every form of social life as those which compose the harvest of the woods.

"There is probably no country—there are few large farms even—where at least one fourth of the soil is not either unfit for agricultural use, or so unproductive that, as pasture or as ploughland, it yields less pecuniary return than a thrifty wood. Every prairie has its sloughs where willows and poplars would find a fitting soil, every Eastern farm its rocky nooks and its barren hillsides suited to the growth of some species from our rich forest flora, and everywhere belts of trees might advantageously be planted along the road-sides and the boundaries and dividing fences. In most cases, it will be found that trees may be made to grow well where cultivated crops will not repay the outlay of tillage, and it is a very plain dictate of sound economy, that if trees produce a better profit than the same ground would return if devoted to grass or grain, the wood should be substituted for the field.

"WOODLAND IN EUROPEAN COUNTRIES.

"In 1862, Rentzsch calculated the proportions of woodland in different European countries as follows:*

Norway	66	per cent.
Sweden	60	"
Russia	30.90	"

*"*Der Wald*, pp. 123, 124."

Germany	26.58	per cent.
Belgium	18.52	"
France	16.79	"
Switzerland	15	"
Sardinia	12.29	"
Neapolitan States	9.43	"
Holland	7.10	"
Spain	5.52	"
Denmark	5.50	"
Great Britain	5	"
Portugal	4.40	"

"The large proportion of woodland in Norway and Sweden is in a great measure to be ascribed to the mountainous character of the surface, which renders the construction of roads difficult and expensive, and hence the forests are comparatively inaccessible, and transportation is too costly to tempt the inhabitants to sacrifice their woods for the sake of supplying distant markets.

"The industries which employ wood as a material have only lately been much developed in these countries, and though the climate requires the consumption of much wood as a fuel, the population is not numerous enough to create, for this purpose, a demand exceeding the annually produced supply, or to need any great extension of cleared ground for agricultural purposes. Besides this, in many places peat is generally employed as domestic fuel. Hence, though Norway has long exported a considerable quantity of lumber,* and the iron and copper works of Sweden consume charcoal very largely, the forests have not diminished rapidly enough to produce very sensible climatic or even economical evils.

"At the opposite end of the scale we find Holland, Denmark, Great Britain, Spain, and Portugal. In the three first named countries a cold and humid climate renders the almost constant maintenance of domestic fires a necessity, while in Great Britain especially the demand of the various industries which depend on wood as a material, or on mechanical power

*"Railway ties, or, as they are called in England, *sleepers*, are largely exported from Norway to India, and sold at Calcutta at a lower price than timber of equal quality can be obtained from the native woods.—*Reports on Forest Conservancy*, vol. I, pt. II, p. 1533.

"From 1861 to 1870 Norway exported annually, on the average, more than 60,000,000 cubic feet of lumber.—Wulfsberg, *Norges Velstandskilder*. Christiania, 1872."

derived from heat, are very great. Coal and peat serve as a combustible instead of wood in them all, and England imports an immense quantity of timber from her foreign possessions. Fortunately, the character of soil, surface, and climate renders the forest of less importance as a geographical agent in these northern regions than in Spain and Portugal, where all physical conditions concur to make a large extent of forest an almost indispensable means of industrial progress and social advancement.

"Rentzsch, in fact, ascribes the political decadence of Spain almost wholly to the destruction of the forest. 'Spain,' observes he, 'seemed destined by her position to hold dominion over the world, and this in fact she once possessed. But she has lost her political ascendency, because, during the feeble administration of the successors of Philip II, her exhausted treasury could not furnish the means of creating new fleets, the destruction of the woods having raised the price of timber above the means of the State.'* On the other hand, the same writer argues that the wealth and prosperity of modern England are in great part due to the supply of lumber, as well as of other material for ship-building, which she imports from her colonies and other countries with which she maintains commercial relations.

"FORESTS OF GREAT BRITAIN.

"The proportion of forest is very small in Great Britain, where, as I have said, on the one hand, a prodigious industrial activity requires a vast supply of ligneous material, but where,

*"*Der Wald*, p. 63. Antonio Ponz (*Viage de España* I, prólogo, p. LXIII), says: 'Nor would this be so great an evil, were not some of them declaimers against *trees*, thereby proclaiming themselves, in some sort, enemies of the works of God, who gave us the leafy abode of Paradise to dwell in, where we should be even now sojourning, but for the first sin, which expelled us from it.'

"I do not know at what period the two Castiles were bared of their woods, but the Spaniard's proverbial 'hatred of a tree' is of long standing. Herrera combats this foolish prejudice; and Ponz, in the prologue to the ninth volume of his journey, says that many carried it so far as wantonly to destroy the shade and ornamental trees planted by the municipal authorities. 'Trees,' they contended, and still believe, 'breed birds, and birds eat up the grain.' Our author argues against the supposition of the 'breeding of birds by trees,' which, he says, is as absurd as to believe that an elm tree can yield pears; and he charitably suggests that the expression is, perhaps, a *manière de dire*, a popular phrase, signifying simply that trees harbor birds."

on the other, the abundance of coal, which furnishes a sufficiency of fuel, the facility of importation of timber from abroad, and the conditions of climate and surface combine to reduce the necessary quantity of woodland to its lowest expression.

"With the exception of Russia, Denmark, and parts of Germany, no European countries can so well dispense with the forests, in their capacity of conservative influences, as England and Ireland. Their insular position and latitude secure an abundance of atmospheric moisture; the general inclination of surface is not such as to expose it to special injury from torrents, and it is probable that the most important climatic action exercised by the forest in these portions of the British empire, is in its character of a mechanical screen against the effects of wind. The due proportion of woodland in England and Ireland is, therefore, a question not of geographical, but almost purely of economical, expediency, to be decided by the comparative direct pecuniary return from forest growth, pasturage, and ploughland.

"Contrivances for economizing fuel came later into use in the British Islands than on the Continent. Before the introduction of a system of drainage, the soil, like the sky, was, in general, charged with humidity; its natural condition was unfavorable for the construction and maintenance of substantial common roads, and the transportation of so heavy a material as coal, by land, from the remote counties where alone it was mined in the Middle Ages, was costly and difficult. For all these reasons, the consumption of wood was large, and apprehensions of the exhaustion of the forests were excited at an early period. Legislation there, as elsewhere, proved ineffectual to protect them, and many authors of the sixteenth century express fears of serious evils from the wasteful economy of the people in this respect.† * * * *

"Evelyn's 'Silva,' the first edition of which appeared in 1664, rendered an extremely important service to the cause of the woods, and there is no doubt that the ornamental plantations in which England far surpasses all other countries, are,

†A foot-note of the author is omitted here.

in some measure, the fruit of Evelyn's enthusiasm. In England, however, arboriculture, the planting and nursing of single trees, has, until comparatively recent times, been better understood than sylviculture, the sowing and training of the forest. But this latter branch of rural improvement now receives great attention from private individuals, though, so far as I know, not from the National Government, except in the East Indian provinces, where the forestal department has assumed great importance.*

"In fact, England is, I believe, the only European country where private enterprise has pursued sylviculture on a really great scale, though admirable examples have been set in many others. In England the law of primogeniture, and other institutions and national customs which tend to keep large estates long undivided and in the same line of inheritance, the wealth of the landholders, the special adaptation of the climate to the growth of forest trees, and the difficulty of finding safe and profitable investments of capital, combine to afford encouragements for the plantation of forests, which scarcely exist elsewhere in the same degree.

"In Scotland, where the country is for the most part broken and mountainous, the general destruction of the forests has been attended with very serious evils, and it is in Scotland that many of the most extensive British forest plantations have now been formed. But although the inclination of surface in Scotland is rapid, the geological constitution of the soil is not of a character to promote such destructive degradation by

* "The improvidence of the population under the native and early foreign governments has produced great devastations in the forests of the British East Indian provinces, and the demands of the railways for fuel and timber have greatly augmented the consumption of lumber, and of course contributed to the destruction of the woods. The forests of British India are now, and for several years have been, under the control of an efficient governmental organization, with great advantage both to the government and to the general private interests of the people.

"The official Reports on Forest Conservancy from May, 1862, to August, 1871, in 4 vols. folio, contain much statistical and practical information on all subjects connected with the administration of the forest.

"Many laws for the protection of the forest, as a cover for game, and for the preservation of ship-timber, were enacted in England before the seventeenth century. The Statutes I Eliz. c. XV, XIII Eliz. c. V, and XXVII Eliz. c. XIX, which have sometimes been understood as designed to discourage the manufacture of iron, were obviously intended to prevent the destruction of large and valuable timber, useful in ordinary and naval architecture, by burning it for charcoal. The injury to the forges was accidental, not the purpose of the laws."

running water as in Southern France, and it has not to contend with the parching droughts by which the devastations of the torrents are rendered more injurious in those provinces.

"It is difficult to understand how either law or public opinion, in a country occupied by a dense and intelligent population, and, comparatively speaking, with an infertile soil, can tolerate the continued withdrawal of a great portion of the territory from the cultivation of trees and from other kinds of rural economy, merely to allow wealthy individuals to amuse themselves with field sports. In Scotland, 2,000,000 acres, as well suited to the growth of forests and for pasture as is the soil generally, are withheld from agriculture, that they may be given up to herds of deer protected by the game laws. A single nobleman, for example, thus appropriates for his own pleasures not less than 100,000 acres.* In this way one tenth of all the land of Scotland is rendered valueless in an economical point of view—for the returns from the sale of the venison and other game scarcely suffice to pay the game-keepers and other incidental expenses—and in these so-called *forests* there grows neither building timber nor fire-wood worth the cutting, as the animals destroy the young shoots.

"FORESTS OF FRANCE.

"The preservation of the woods was one of the wise measures recommended to France by Sully, in the time of Henry IV, but the advice was little heeded, and the destruction of the forests went on with such alarming rapidity, that, two generations later, Colbert uttered the prediction: 'France will perish for want of wood.' Still, the extent of wooded soil was very great, and the evils attending its diminution were not so sensibly felt, that either the government or public opinion saw the necessity of authoritative interference, and in 1750 Mirabeau estimated the remaining forests of the kingdom at seventeen millions of hectares [42,000,000 acres]. In 1860 they were reduced to eight millions [19,769,000 acres], or at the rate of 82,000 hectares [202,600 acres] per year. Troy,

* "Robertson, *Our Deer Forests*. London, 1867."

from whose valuable pamphlet, *Étude sur le Reboisement des Montagnes*, I take these statistical details, supposes that Mirabeau's statement may have been an extravagant one, but it still remains certain that the waste has been enormous; for it is known that, in some departments, that of Ariège, for instance, clearing has gone on during the last half century at the rate of three thousand acres a year, and in all parts of the empire trees have been felled faster than they have grown.* The total area of France in Mirabeau's time, excluding Savoy, but including Alsace and Lorraine, was about one hundred and thirty-one millions of acres. The extent of forest supposed by Mirabeau would be about thirty-two per cent. of the whole territory. In a country and a climate where the conservative influences of the forest are so necessary as in France, trees must cover a large surface and be grouped in large masses, in order to discharge to the best advantage the various functions assigned to them by nature. The consumption of wood is rapidly increasing in that empire, and a large part of its territory is mountainous, sterile, and otherwise such in character or situation that it can be more profitably devoted to the growth of wood than to any agricultural use. Hence it is evident that the proportion of forest in 1750, taking even Mirabeau's large estimate, was not very much too great for permanent maintenance, though doubtless the distribution was so unequal that it would have been sound policy to fell the woods and clear land in some provinces, while large forests

* "Among the indirect proofs of the comparatively recent existence of extensive forests in France, may be mentioned the fact that wolves were abundant, not very long since, in parts of the empire where there are now neither wolves nor woods to shelter them. Arthur Young more than once speaks of the 'innumerable multitudes' of these animals which infested France in 1789, and George Sand states, in the *Histoire de ma Vie*, that some years after the restoration of the Bourbons, they chased travelers on horseback in the southern provinces, and literally knocked at the doors of her father-in-law's country seat. Eugénie de Guérin, writing from Rayssac in Languedoc in 1831, speaks of hearing the wolves fighting with dogs in the night under her very windows. *Lettres*, 2d ed., p. 6.

"There seems to have been a tendency to excessive clearing in Central and Western, earlier than in Southeastern, France. Bernard Palissy, in the *Recepte Véritable*, first printed in 1563, thus complains: 'When I consider the value of the least clump of trees, or even of thorns, I much marvel at the great ignorance of men, who, as it seemeth, do nowadays study only to break down, fell, and waste the fair forests which their forefathers did guard so choicely. I would think no evil of them for cutting down the woods, did they but replant again some part of them; but they care nought for the time to come, neither reck they of the great damage they do to their children which shall come after them.'—*Œuvres Complètes de* Bernard Palissy, 1844, p. 88.

should have been planted in others.* During the period in question France neither exported manufactured wood or rough timber, nor derived important collateral advantages of any sort from the destruction of her forests. She is consequently impoverished and crippled to the extent of the difference between what she actually possesses of wooded surface and what she ought to have retained.†

"The force of the various considerations which have been suggested in regard to the importance of the forest has been generally felt in France, and the subject has been amply debated in special treatises, in scientific journals, and by the public press, as well as in the legislative body of that country. Perhaps no one point has been more prominent in the discussions than the influence of the forest in equalizing and regulating the flow of the water of precipitation. Opinion is still somewhat divided on this subject, but the value of the woods as a safeguard against the ravages of torrents is universally acknowledged, and it is hardly disputed that the rise of river-floods is, even if as great, at least less sudden in streams having their sources in well-wooded territory.

"Upon the whole, the conservative action of the woods in regard to torrents and to inundations has been generally recognized by the public of France as a matter of prime importance, and the Government of the empire has made this principle the basis of a special system of legislation for the

* "The view I have taken of this point is confirmed by the careful investigations of Rentzsch, who estimates the proper proportion of woodland to entire surface at twenty-three per cent. for the interior of Germany, and supposes that near the coast, where the air is supplied with humidity by evaporation from the sea, it might safely be reduced to twenty per cent. See Rentzsch's very valuable prize essay, *Der Wald im Haushalt der Natur und der Volkswirthschaft*, cap. VIII.

"The due proportion in France would considerably exceed that for the German States, because France has relatively more surface unfit for any growth but that of wood, because the form and geological character of her mountains expose her territory to much greater injury from torrents, and because at least her southern provinces are more frequently visited both by extreme droughts and by deluging rains."

† "In 1863, France imported lumber to the value of twenty-five and a half millions of dollars, and exported to the amount of six and a half millions of dollars. The annual consumption of France was estimated in 1866 at 212,000,000 cubic feet for building and manufacturing, and 1,588,500,000 for fire-wood and charcoal. The annual product of the forest-soil of France does not exceed 70,000,000 cubic feet of wood fit for industrial use, and 1,300,000,000 cubic feet consumed as fuel. This estimate does not include the product of scattered trees on private grounds, but the consumption is estimated to exceed the production of the forests by the amount of about twenty millions of dollars. It is worth noticing that the timber for building and manufacturing produced in France comes almost wholly from the forests of the state or of the communes.—Jules Clavé, in *Revue des Deux Mondes* for March 1, 1866, p. 207."

protection of existing forests, and for the formation of new. The clearing of woodland, and the organization and functions of a police for its protection, are regulated by a law bearing date June 18th, 1859, and provision was made for promoting the restoration of private woods by a statute adopted on the 28th of July, 1860. The former of these laws passed the legislative body by a vote of 246 against 4, the latter with but a single negative voice. The influence of the Government, in a country where the throne is so potent as in France, would account for a large majority, but when it is considered that both laws, the former especially, interfere very materially with the rights of private domain, the almost entire unanimity with which they were adopted is proof of a very general popular conviction, that the protection and extension of the forests is a measure more likely than any other to arrest the devastations of the torrents and check the violence, if not to prevent the recurrence, of destructive river inundations. The law of July 28th, 1860, appropriated 10,000,000 francs, to be expended, at the rate of 1,000,000 francs per year, in executing or aiding the replanting of woods. It is computed that this appropriation—which, considering the vast importance of the subject, does not seem extravagant for a nation rich enough to be able to expend annually six hundred times that sum in the maintenance of its military establishments in times of peace—will secure the creation of new forest to the extent of about 200,000 acres, or one fourteenth part of the soil, where the restoration of the woods is thought feasible, and, at the same time, specially important as a security against the evils ascribed, in a great measure, to its destruction.*

*"In 1848 the Government of the so-called French Republic sold to the Bank of France 187,000 acres of public forests, and notwithstanding the zeal with which the Imperial Government had pressed the protective legislation of 1860, it introduced into the Legislative Assembly in 1865 a bill for the sale, and consequently destruction, of the forests of the state to the amount of one hundred million francs. The question was much debated in the Assembly, and public opinion manifested itself so energetically against the measure that the ministry felt itself compelled to withdraw it. See the discussions in *L'Aliénation des Forêts de l'État*. Paris, 1865.

"The late Imperial Government sold about 170,000 acres of woodland between 1852 and 1866, both inclusive. The other Governments, since the restoration of the Bourbons in 1814, alienated more than 700,000 acres of the public forests, exclusive of sales between 1836 and 1857, which are not reported.—*Annuaire des Eaux et Forêts*, 1872, p. 9."

"In 1865 the Legislative Assembly passed a bill amendatory of the law of 1860, providing, among other things, for securing the soil in exposed localities by grading, and by promoting the growth of grass and the formation of greensward over the surface. This has proved a most beneficial measure, and its adoption under corresponding conditions in the United States is most highly to be recommended. The leading features of the system are:

"1. Marking out and securing from pasturage and all other encroachments a zone along the banks and around the head of ravines.

"2. Turfing this zone, which in France accomplishes itself, if not spontaneously, at least with little aid from art.

"3. Consolidation of the scarps of the ravines by grading and wattling and establishing barriers, sometimes of solid masonry, but generally of fascines or any other simple materials at hand, across the bed of the stream.

"4. Cutting *banquettes* or narrow terraces along the scarps, and planting rows of small deciduous trees and arborescent shrubs upon them, alternating with belts of grass obtained by turfing with sods or sowing grass-seeds. Planting the banquettes and slopes with bushes, and sowing any other vegetables with tenacious roots, is also earnestly recommended.*

"REMEDIES AGAINST TORRENTS.

"The rural population, which in France is generally hostile to all forest laws, soon acquiesced in the adoption of this system, and its success has far surpassed all expectation. At the end of the year 1868 about 190,000 acres had been planted with trees,† and nearly 7,000 acres well turfed over in the

*"See a description of similar processes recommended and adopted by Mengotti, in his *Idraulica*, vol. II, chap. XVII."

†"Travelers spending the winter at Nice may have a good opportunity of studying the methods of forming and conducting the re-wooding of mountain slopes, under the most unfavorable conditions, by visiting Mont Boron, in the immediate vicinity of that city, and other coast plantations in that province, where great difficulties have been completely overcome by the skill and perseverance of French foresters. See *Les Forêts des Maures*, *Revue des Eaux et Forêts*, January, 1869.

"Still more formidable difficulties have been vanquished in re-wooding Mont Faron near Toulon, and it is hardly hyperbolical to say that this is a case of impossibilities conquered. See *Revue des Eaux et Forêts*, February, 1873.

Department of the Hautes Alpes. Many hundred ravines, several of which had been the channels of formidable torrents, had been secured by barriers, grading and planting, and according to official reports the aspect of the mountains in the Department, wherever these methods were employed, had rapidly changed. The soil had acquired such stability that the violent rains of 1868, so destructive elsewhere, produced no damage in the districts which had been subjected to these operations, and numerous growing torrents which threatened irreparable mischief had been completely extinguished, or at least rendered altogether harmless.*

"Besides the processes directed by the Government of France, various subsidiary measures of an easily and economically practicable character have been suggested. Among them is one which has long been favorably known in our Southern States under the name of *circling*, and the adoption of which in hilly regions in other States is to be strongly recommended.

"It is simply a method of preventing the wash of surface by rains, and at the same time of providing a substitute for irrigation of steep pasture grounds, consisting in little more than in running horizontal furrows along the hillsides, thus converting the scarp of the hills into a succession of small terraces which, when once turfed over, are very permanent. Experience is said to have demonstrated that this simple process at least partially checks the too rapid flow of surface-water into the valleys, and, consequently, in a great measure obviates one of the most prominent causes of inundations, and that it suffices to retain the water of rains, of snows, and of small springs, long enough for the irrigation of the soil, thus increasing its product of herbage in a five-fold proportion.†

"As a further recommendation, it may be observed that this process is an admirable preparation of the ground for

*"For ample details of processes and results, see the second volume of Surell, *Étude sur les Torrents*, Paris, 1872, and a Report by De La Grye, in the *Revue des Eaux et Forêts* for January, 1869."

†"Troy, *Étude sur le Reboisement des Montagnes*, §§ 6, 7, 21."

forest plantations, as young trees planted on the terraces would derive a useful protection from the form of the surface and the coating of turf, and would also find a soil moist enough to secure their growth.

"FORESTS OF ITALY.

"According to the most recent statistics, Italy has 17.64 per cent. of woodland,* a proportion which, considering the character of climate and surface, the great amount of soil which is fit for no other purpose than the growth of trees, and the fact that much of the land classed as forest is either very imperfectly wooded, or covered with groves badly administered, and not in a state of progressive improvement, might advantageously be doubled. Taking Italy as a whole, we may say that she is eminently fitted by climate, soil, and superficial formation, to the growth of a varied and luxuriant arboreal vegetation, and that in the interests of self-protection, the promotion of forestal industry is among the first duties of her people. There are in Western Piedmont valleys where the felling of the woods has produced consequences geographically and economically as disastrous as in Southeastern France, and there are many other districts in the Alps and the Apennines where human improvidence has been almost equally destructive. Some of these regions must be abandoned to absolute desolation, and for others the opportunity of physical restoration is rapidly passing away. But there are still millions of square miles which might profitably be planted with forest trees, and thousands of acres of parched and barren hillside, within sight of almost every Italian provincial capital, which might easily and shortly be re-clothed with verdant woods.†

*"Siemoni, *Manuale d'Arte Forestale*, 2 ediz., Firenze, 1872, p. 542."

†"To one accustomed to the slow vegetation of less favored climes, the rapidity of growth in young plantations in Italy seems almost magical. The trees planted along the new drives and avenues in Florence have attained in three or four years a development which would require at least ten in our Northen States. This, it is true, is a special case, for the trees have been planted and tended with a skill and care which cannot be bestowed upon a forest; but the growth of trees little cared for is still very rapid in Italy. According to Toscanelli, *Economia rurale nella Provincia di Pisa*, p. 8, *note*—one of the most complete, curious, and instructive pictures of rural life which exists in any literature—the white poplar, *Populus alba*, attains in the valley of the Serchio a great height, with a mean diameter of two feet, in twenty years. Selmi states in his *Miasma Palustre*, p. 115,

"The denudation of the Central and Southern Apennines and of the Italian declivity of the Western Alps began at a period of unknown antiquity, but it does not seem to have been carried to a very dangerous length until the foreign conquests and extended commerce of Rome created a greatly increased demand for wood for the construction of ships and for military material.* The Eastern Alps, the Western Apennines, and the Maritime Alps retained their forests much later; but even here the want of wood, and the injury to the plains and the navigation of the rivers by sediment brought down by the torrents, led to legislation for the protection of the forests, by the Republic of Venice, at various periods between the fifteenth and the nineteenth centuries,† by that of Genoa as early at least as the seventeenth; and both these Governments, as well as several others, passed laws requiring the proprietors of mountain lands to replant the woods. These, however, seem to have been little observed, and it is generally true that the present condition of the forest in Italy is much less due to the want of wise legislation for its protection than to the laxity of the Governments in enforcing their laws.

"It is very common in Italy to ascribe to the French occupation under the first Empire all the improvements and all the abuses of recent times, according to the political sympathies of the individual; and the French are often said to have prostrated every forest which has disappeared within this century. But, however this may be, no energetic system of repression or restoration was adopted by any of the Italian States after the downfall of the Empire, and the taxes on forest property in some of them were so burdensome that rural municipalities sometimes proposed to cede their common woods to the Government, without any other compensation than the remission of the taxes imposed on forest lands.‡ Under such circum-

that the linden reaches a diameter of sixteen inches in the same period. The growth of foreign trees is sometimes extremely luxuriant in Italy. Two Atlas cedars, at the well-known villa of Careggi, near Florence, grown from seed sown in 1850, measure twenty inches in diameter, above the swell of the roots, with an estimated height of sixty feet."

*† Two foot-notes of the author are omitted here.

‡"See the *Politecnico* for the month of May, 1862, p. 234."

stances, woodlands would soon become disafforested, and where facilities of transportation and a good demand for timber have increased the inducements to fell it, as upon the borders of the Mediterranean, the destruction of the forest and all the evils which attend it have gone on at a seriously alarming rate.

"Gallenga gives a striking account of the wanton destruction of the forests in Northern Italy within his personal recollection,* and there are few Italians past middle life whose own memory will not supply similar reminiscences. The clearing of the mountain valleys of the provinces of Bergamo and of Brescia is recent, and Lombardini informs us the felling of the woods in the Valtelline commenced little more than forty years ago.

"Although no country has produced more able writers on the value of the forest and the general consequences of its destruction than Italy, yet the specific geographical importance of the woods, except as a protection against inundations, has not been so clearly recognized in that country as in the States bordering it on the north and west. It is true that the face of nature has been as completely revolutionized by man, and that the action of torrents has created almost as wide and as hopeless devastation in Italy as in France; but in the French Empire the recent desolation produced by clearing the forests is more extensive, has been more suddenly effected, has occurred in less remote and obscure localities, and, therefore, excites a livelier and more general interest than in Italy, where public opinion does not so readily connect the effect with its true cause. Italy, too, from ancient habit, employs little wood in architectural construction; for generations she has maintained no military or commercial marine large enough to require exhaustive quantities of timber,† and the mildness

*"'Far away in the darkest recesses of the mountains a kind of universal conspiracy seems to have been got up among these Alpine people—a destructive mania to hew and sweep down everything that stands on roots.'—*Country Life in Piedmont*, p. 134.

"'There are huge pyramids of mountains now bare and bleak from base to summit, which men still living and still young remember seeing richly mantled with all but primeval forests.'—*Ibid*, p. 135."

†A foot-note of the author is omitted here.

of her climate makes small demands on the woods for fuel. Besides these circumstances, it must be remembered that the sciences of observation did not become knowledges of practical application till after the mischief was already mainly done and even forgotten in Alpine Italy, while its evils were just beginning to be sensibly felt in France when the claims of natural philosophy as a liberal study were first acknowledged in modern Europe. The former political condition of the Italian Peninsula would have effectually prevented the adoption of a general system of forest economy, however clearly the importance of a wise administration of this great public interest might have been understood. The woods which controlled and regulated the flow of the river-sources were very often in one jurisdiction, the plains to be irrigated, or to be inundated by floods and desolated by torrents, in another. Concert of action, on such a subject, between a multitude of jealous petty sovereignties, was obviously impossible, and nothing but the permanent union of all the Italian States under a single government can render practicable the establishment of such arrangements for the conservation and restoration of the forests, and the regulation of the flow of the waters, as are necessary for the full development of the yet unexhausted resources of that fairest of lands, and even for the maintenance of the present condition of its physical geography.

"THE FORESTS OF GERMANY.

"Germany, including a considerable part of the Austrian Empire, from character of surface and climate, and from the attention which has long been paid in all the German States to sylviculture, is in a far better condition in this respect than its more southern neighbors; and though in the Alpine provinces of Bavaria and Austria the same improvidence which marks the rural economy of the corresponding districts of Switzerland, Italy, and France, has produced effects hardly

less disastrous,* yet, as a whole, the German States, as Siemoni well observes, must be considered as in this respect the model countries of Europe. Not only is the forest area in general maintained without diminution, but new woods are planted where they are specially needed,† and, though the slow growth of forest trees in those climates reduces the direct pecuniary returns of woodlands to a minimum, the governments wisely persevere in encouraging this industry. The exportation of sawn lumber from Trieste is large, and in fact the Turkish and Egyptian markets are in great part supplied from this source.‡

"FORESTS OF RUSSIA.

"Russia, which we habitually consider as substantially a forest country—which has in fact a large proportion of woodland—is beginning to suffer seriously for want of wood. Jourdier observes: 'Instead of a vast territory with immense forests, which we expect to meet, one sees only scattered groves thinned by the wind or by the axe of the *moujik*, grounds cut

*"As an instance of the scarcity of fuel in some parts of the territory of Bavaria, where, not long since, wood abounded, I may mention the fact that the water of salt springs is, in some instances, conveyed to the distance of sixty miles, in iron pipes, to reach a supply of fuel for boiling it down.

"In France, the juice of the sugar-beet is sometimes carried three or four miles in pipes for the same reason.

"Many of my readers may remember that it was not long ago proposed to manufacture the gas for the supply of London at the mouths of the coal mines, and convey it to the city in pipes, thus saving the transportation of the coal; but as the coke and mineral tar would still have remained to be disposed of, the operation would probably not have proved advantageous.

"Great economy in the production of petroleum has resulted from the application of cast-iron tubes to the wells instead of barrels; the oil is thus carried over the various inequalities of surface for three or four miles to the tanks on the railroads, and forced into them by steam engines. The price of transport is thus reduced one fifth."

†"The Austrian Government is making energetic efforts for the propagation of forests on the desolate waste of the Karst. The difficulties from drought and from the violence of the winds, which might prove fatal to young and even to somewhat advanced plantations, are very serious, but in 1866 upwards of 400,000 trees had been planted and great quantities of seeds sown. Thus far, the results of this important experiment are said to be encouraging. See the *Chronique Forestière* in the *Revue des Eaux et Forêts*, February, 1870.

"Later accounts state that the government nurseries of the Karst supplied between 1869–1872 26,000,000 young forest trees for planting, and that of 70,000 ash trees planted in the Karst, scarcely one failed to grow."

‡"For information respecting the forests of Germany, as well as other European countries, see, besides the works already cited, the very valuable *Manuale d'Arte Forestale* of Siemoni, 2de edizione, Firenze, 1872."

over and more or less recently cleared for cultivation. There is probably not a single district in Russia which has not to deplore the ravages of man or of fire, those two great enemies of Muscovite sylviculture. This is so true, that clear-sighted men already foresee a crisis which will become terrible, unless the discovery of great deposits of some new combustible, as pit-coal or anthracite, shall diminish its evils.'*

"FORESTS OF UNITED STATES.

"I greatly doubt whether any one of the American States, except, perhaps, Oregon, has, at this moment, more woodland than it ought permanently to preserve, though, no doubt, a different distribution of the forests in all of them might be highly advantageous. It is, perhaps, a misfortune to the American Union that the State Governments have so generally disposed of their original domain to private citizens. It is true that public property is not sufficiently respected in the United States; and within the memory of almost every man of mature age, timber was of so little value in the northernmost States that the owners of private woodlands submitted, almost without complaint, to what would be regarded elsewhere as very aggravated trespasses upon them.† Persons in want of timber helped themselves to it wherever they could find it, and a claim for damages, for so insignificant a wrong as cutting down and carrying off a few pine or oak trees, was regarded as a mean-spirited act in a proprietor. The habits formed at this period are not altogether obsolete, and even now the notion of a common right of property in the woods still

* A foot-note of the author is omitted here.

† "According to the maxims of English jurisprudence, the common law consists of general customs so long established that 'the memory of man runneth not to the contrary.' In other words, long custom makes law. In new countries, the change of circumstances creates new customs, and, in time, new law, without the aid of legislation. Had the American colonists observed a more sparing economy in the treatment of their woods, a new code of customary forest law would have sprung up and acquired the force of a statute. Popular habit was fast elaborating the fundamental principles of such a code, when the rapid increase in the value of timber, in consequence of the reckless devastation of the woodlands, made it the interest of the proprietors to interfere with this incipient system of forest jurisprudence, and appeal to the rules of English law for the protection of their woods. The courts have sustained these appeals, and forest property is now legally as inviolable as any other, though common opinion still combats the course of judicial decision on such questions."

lingers, if not as an opinion at least as a sentiment. Under such circumstances it has been difficult to protect the forest, whether it belong to the State or to individuals. Property of this kind is subject to plunder, as well as to frequent damage by fire. The destruction from these causes would, indeed, considerably lessen, but would by no means wholly annihilate the climatic and geographical influences of the forest, or ruinously diminish its value as a regular source of supply of fuel and timber.

"It is evidently a matter of the utmost importance that the public, and especially land-owners, be roused to a sense of the dangers to which the indiscriminate clearing of the woods may expose not only future generations, but the very soil itself. Some of the American States, as well as the Governments of many European colonies, still retain the ownership of great tracts of primitive woodland. The State of New York, for example, has, in its northeastern counties, a vast extent of territory in which the lumberman has only here and there established his camp, and where the forest, though interspersed with permanent settlements, robbed of some of its finest pine groves, and often ravaged by devastating fires, still covers far the largest proportion of the surface. Through this territory the soil is generally poor, and even the new clearings have little of the luxuriance of harvest which distinguishes them elsewhere. The value of the land for agricultural uses is therefore very small, and few purchases are made for any other purpose than to strip the soil of its timber. It has been often proposed that the State should declare the remaining forest the inalienable property of the Commonwealth, but I believe the motive of the suggestion has originated rather in poetical than in economical views of the subject. Both these classes of considerations have a real worth. It is desirable that some large and easily accessible region of American soil should remain, as far as possible, in its primitive condition, at once a museum for the instruction of the student, a garden for the recreation of the lover of nature, and an asylum where indigenous tree, and humble plant that loves the

shade, and fish and fowl and four-footed beast, may dwell and perpetuate their kind, in the enjoyment of such imperfect protection as the laws of a people jealous of restraint can afford them. The immediate loss to the public treasury from the adoption of this policy would be inconsiderable, for these lands are sold at low rates. The forest alone, economically managed, would, without injury, and even with benefit to its permanence and growth, soon yield a regular income larger than the present value of the fee.

"The collateral advantages of the preservation of these forests would be far greater. Nature threw up those mountains and clothed them with lofty woods, that they might serve as a reservoir to supply with perennial waters the thousand rivers and rills that are fed by the rains and snows of the Adirondacks, and as a screen for the fertile plains of the central counties against the chilling blasts of the north wind, which meet no other barrier in their sweep from the Arctic pole. The climate of Northern New York even now presents greater extremes of temperature than that of Southern France. The long-continued cold of winter is more intense, the short heats of summer even fiercer than in Provence, and hence the preservation of every influence that tends to maintain an equilibrium of temperature and humidity is of cardinal importance. The felling of the Adirondack woods would ultimately involve for Northern and Central New York consequences similar to those which have resulted from the laying bare of the southern and western declivities of the French Alps and the spurs, ridges, and detached peaks in front of them.

"It is true that the evils to be apprehended from the clearing of the mountains of New York may be less in degree than those which a similar cause has produced in Southern France, where the intensity of its action has been increased by the inclination of the mountain declivities, and by the peculiar geological constitution of the earth. The degradation of the soil is, perhaps, not equally promoted by a combination of the same circumstances, in any of the American Atlantic States, but still they have rapid slopes and loose and friable soils

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enough to render widespread desolation certain, if the further destruction of the woods is not soon arrested. The effects of clearing are already perceptible in the comparatively unviolated region of which I am speaking. The rivers which rise in it flow with diminished currents in dry seasons, and with augmented volumes of water after heavy rains. They bring down larger quantities of sediment, and the increasing obstructions to the navigation of the Hudson, which are extending themselves down the channel in proportion as the fields are encroaching upon the forest, give good grounds for the fear of irreparable injury to the commerce of the important towns on the upper waters of that river, unless measures are taken to prevent the expansion of 'improvements' which have already been carried beyond the demands of a wise economy.

"In the Eastern United States the general character of the climate, soil, and surface is such, that for the formation of very destructive torrents a much longer time is required than would be necessary in the mountainous provinces of Italy or of France. But the work of desolation has begun even there, and wherever a rapid mountain-slope has been stripped of wood, incipient ravines already plough the surface, and collect the precipitation in channels which threaten serious mischief in the future. There is a peculiar action of this sort on the sandy surface of pine-forests and in other soils that unite readily with water, which has excited the attention of geographers and geologists. Soils of the first kind are found in all the Eastern States; those of the second are more frequent in the exhausted counties of Maryland, where tobacco is cultivated, and in the more southern territories of Georgia and Alabama. In these localities the ravines which appear after the cutting of the forest, through some accidental disturbance of the surface, or, in some formations, through the cracking of the soil in consequence of great drought or heat, enlarge and extend themselves with fearful rapidity.

"In Georgia and in Alabama, Lyell saw 'the beginning of the formation of hundreds of valleys in places where the prim-

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itive forest had been recently cut down.' One of these, in Georgia, in a soil composed of clay and sand produced by the decomposition *in situ* of hornblendic gneiss with layers and veins of quartz, 'and which did not exist before the felling of the forest twenty years previous,' he describes as more than 55 feet in depth, 300 yards in length, and from 20 to 180 feet in breadth. Our author refers to other cases in the same States, 'where the cutting down of the trees, which had prevented the rain from collecting into torrents and running off in sudden land-floods, has given rise to ravines from 70 to 80 feet deep.'*

"Similar results often follow in the Northeastern States from cutting the timber on the 'pine plains,' where the soil is usually of a sandy composition and loose texture."

* "Lyell, *Principles of Geology*, 10th ed., vol. I, 345–6."

GEOLOGICAL SURVEY OF KENTUCKY.

N. S. SHALER, DIRECTOR.

ANNUAL REPORT OF N. S. SHALER

FOR THE YEAR 1876.

PART IV. VOL. III. SECOND SERIES.

ANNUAL REPORT OF N. S. SHALER FOR THE YEAR 1876.

The laws constituting the Geological Survey of Kentucky provide that the Director of the Survey shall annually make a report of the progress of the Survey to the Governor of the Commonwealth. It is to be presumed that the object of this requirement was to secure the presentation to the public, at no greater intervals than one year, detailed statements concerning the progress of the work of the Survey in a more connected manner than such accounts could be obtained by the record that is made in the usual economic and scientific reports. Believing this to be the object of this requisition, I shall now proceed to give an account of the doings of the Survey during the year 1876.

It is one of the many disadvantages of conducting a great public work by periodical grants of money rather than by the appropriations of a continuous kind, that the Director is in continual doubt as to the future of his labors. His plans must constantly take the shape that will permit the closure of the work without the loss of a large part of the expenditure in efforts which, on account of their incompleteness, have failed to bring a return. This doubt of the future of the Survey was intensified by the grave pecuniary distress which hung over the country at the time of the assembling of the Legislature of the Commonwealth in December, 1875; and it was not until the nineteenth of February, 1876, that the passage of the bill appropriating forty-four thousand dollars for the continuance of the researches and publication work of the Survey, during the coming two years, made it possible to lay the plans for further work. The passage at the same date of a bill providing for the exhibition at Philadelphia of the mineral

resources of the Commonwealth, and the connection established by the law between this work and the Geological Survey, added an additional burden to the usual work of the Survey. The time allowed by the authorities of the Centennial Exhibition for the reception of collections at Philadelphia, made it necessary for me to turn the whole force of the Geological Survey to the work of collecting, arranging, and forwarding specimens. At the request of the Centennial Board, Assistants A. R. Crandall and John H. Talbutt were sent with the collections to Philadelphia, where they were detained until June 1st in the work of installation. Other members of the Survey were engaged in securing such collections of ores, coals, soils, &c., as had not already been collected in the field operations of the Survey. With the assistance of Mr. John R. Procter and the other officers of the Survey, I was enabled to prepare a synopsis of the results that had been attained in the studies of the progress of our work, which was published in pamphlet form, under the title of "A General Account of the Commonwealth of Kentucky." This pamphlet, containing over one hundred pages of text, together with a general geological map of the Commonwealth, a map of the southern part of North America, and illustrative sections of its principal coal fields, constituted the most important publication of all those which were freely distributed at the Centennial Exhibition. Several thousand copies were given to persons who were desirous of procuring special information concerning the resources of our country. It is believed the effect of this distribution of information cannot be otherwise than important for the future of the interest of the Commonwealth.

Although the small means at the command of the Survey, or the Centennial Commission, made it out of the question to build a special building, or in other ways to compete with several other States in the showier elements of an exposition of resources, there is no doubt that, taking into account the number of specimens of minerals, soils, building stones, &c., shown, and the extent to which the chemical composition and other characters were set forth, the Commonwealth of Ken-

tucky had the finest mineral display of any of the States in this Union. About eight hundred specimens of coal and iron, each representing some important element of our resources, and each accompanied with a carefully written label, were on exhibition. Our soils, marls, potter's clays, &c., were also well represented. By these several means the student was enabled to form a tolerably good idea of the conditions of the Commonwealth. The geological map, a large copy of which was hung in the exhibit, gave him a tolerably clear idea of the contour and general conditions of the State. The several collections of soils enabled him to see the structure of these deposits in a very clear way, and the specimens of coals, irons, &c., showed the nature of its more hidden treasures. In addition to the material evidences of our resources, the State was represented through the means of about one hundred photographs of its surface and its caverns. The success of this process of illustrating the State has been so great, that the Survey will continue it with the hope of obtaining photographs of each county in the Commonwealth, giving thereby a more complete understanding of the nature of its surface conditions than could be obtained in any other way. Verbal description is at best an inadequate means of setting forth the character of the surface in any district, and it will receive a great aid from this unquestionable testimony of the sun. These photographs will, when published, be accompanied by a map of the district where they were taken, on which the point of view of each photograph will be indicated, the direction of the view being shown by an arrow. A small volume of descriptive letterpress will explain the features shown in the photograph, setting forth the geological structure, the character of the soil, timber, and other facts that might serve to complete the picture. The first series of these photographs will include about one hundred views, and from one to two hundred pages of illustrative text. This series will be ready for publication during the present year. In order to complete the photographic illustration of the State, it will be necessary to secure about six hundred views of the same character. These should

be so arranged as to include a complete study of all the river valleys of the State, following the streams from their head waters to their confluences with the Ohio, and also a complete series of views on that noble stream, the greatest possession of the Commonwealth. The mountain region of the State, its magnificent forests, from the cypress woods of the Mississippi to the pine forests of the Cumberland Mountain, should also be completely represented. The work should be carried further; the growing crops and the great herds of the State, should also be shown in a similar fashion. The cost of obtaining negatives of six hundred views within the State would not exceed four thousand dollars. The plates of the accompanying letterpress would not cost more than half this sum. The views could be furnished separately, or by counties or river valleys, and so brought within the means of those who might desire to have a complete representation of any particular part of the Commonwealth. These photographs, with the accompanying letterpress, could be furnished at from twenty-five to forty cents each. A certain sale for the whole collection would be found in great libraries and wealthy collectors of such prints; but the great advantage to the State would be found in the opportunity to furnish persons intending to make investments in the State with accurate representations of particular districts. An exposition of its resources is something our State will be called on frequently to make in the exhibitions which have become so prominent a feature of our civilization. There is no other means of doing this so effectively as by means of such representations as are given by photographs. With a good map and a set of photographs carefully designed to supplement its teachings, the observer will learn as much as he could do by an ordinary journey. With such a collection placed in the State Capitol, our people would soon come to know more of their native land than is known by any one save one or two officers of the Survey.

The work done by the Survey in connection with the Philadelphia Exposition was not limited to the setting up of a collection and the attendance thereon. The officers in charge of

the collection devoted their whole time to the task of securing an understanding of the resources of the State on the part of those whose occupations were of a nature to make such understanding important. It is believed that almost all the persons interested in the mineral resources exhibited at Philadelphia had ample opportunity to become acquainted with the resources of Kentucky.

As the work of supervising and explaining the Cabinet at Philadelphia was very great, Mr. Procter, under whose charge the collection was immediately placed, was aided, from time to time, by other assistants of the Survey. Eight officers of the Survey thus shared in the work of explaining the resources of the State. This arrangement permitted, also, the work of inquiry into the branches of the exhibition which might prove of especial value to the Commonwealth of Kentucky. As the Geological Survey became the agent of all the special relations which were established between the Commonwealth and the exhibition, this work could not properly be passed by. It was therefore determined to divide up the task of considering certain branches of industry connected with agriculture, mining, or other branches of practical geology, so that the officers of the Survey might be enabled to make reports concerning these several subjects, to serve as summaries of the teachings of the exhibition on certain of the more important existing and prospective industries of Kentucky. These reports are now in preparation, and will include, among other matters, the following important reports: on the potter's clays and their uses; on timber resources; on the washing and coking of coals; on the treatment of iron ores; on the growth and treatment of hemp and flax; on building materials; on agricultural drainage; on the methods of exhibition of the resources of a State. These reports, some of which are now ready for the press, will be included in the sixth volume of economic reports of the Survey.

The officers of the Survey succeeded in obtaining at Philadelphia about one thousand varieties of field and garden seeds of kinds deemed likely to be of value in our State. These

seeds have been extensively distributed to the agriculturalists of the State, with a view to a full trial of their capabilities. This inquiry will aid in the study of our soils, a matter which has long been a subject of special inquiry for the Survey, by enabling us to compare certain well known foreign soils with our own, through the product they give under particular forms of cultivation. A full report of the character of these seeds, and the results of their cultivation, as far as obtained during the year 1877, will be embodied in the sixth volume of reports.

The several tasks undertaken in connection with the exhibition at Philadelphia were of course of a nature that admitted of no postponement, so the usual field and office work of the Survey, during 1876, has been much more limited than was desired. The topographical work has been less hampered than any other part of the operations of the Survey, as it was not necessary to detach more than one officer of that corps for special work. Assistant W. B. Page was engaged during the months of March, April, and a part of May, in the preparation of a large wall map, to be exhibited with the collection at Philadelphia. In the month of May, as soon as the condition of the roads permitted, he resumed the work on the eastern face of the western coal field. The object of this work, as set forth in the reports for 1875, was to make the basis for a map of this important mineral district. The party was organized with Mr. Eugene Underwood, jr., Mr. Jos. B. Hoeing, and Mr. M. S. Cole as aids, the whole being arranged to insure the most rapid mapping of the district lying between the Louisville, Paducah and Southwestern Railway to the Ohio river, including a strip about twenty-four miles wide, within the boundaries of which all the outlines of the singular margin of this field are found. This, with the work done in Edmonson, Grayson, Butler, and Hart, the results of which have been published in the second volume of reports, completes the outline of the eastern border of this field, and gives the basis for those detailed geological studies which are necessary in order to unravel its complicated structure. This season's work in this district added about one thousand miles to the area of the

State, of which we possess an accurate geographical knowledge, and was satisfactory in all its results. At the same rate of advance it will be possible to complete the work of mapping the whole of the outline of this field in two more years of work. The work of filling in the interior region can then go on with relatively great rapidity.

I have felt it necessary to push the topographical work in this western coal field, not only because of the great value it has on account of its richness of resources, and their general accessibility to transportation, but also for the reason that this district has been subjected to far more extensive dislocation than any other part of the State outside of the valley of the upper Cumberland. Faults, folds, ancient erosion, and irregular deposition of beds, all combine to make it the seat of more complication of structure than any other part of the Mississippi Valley that is known to me. It will be readily understood that these local peculiarities cannot be traced out or described without maps on which they can be delineated with accuracy and clearness. The whole of this coal field can be completely and accurately mapped within four years from the present time, provided the same average of working force can be maintained each year within its borders. There will then be no difficulty in indicating with clearness the position of each important coal or iron deposit that occurs there. As it is, with no map that gives even approximately the position of the smaller streams or the roads, and where even the largest rivers are so rudely represented that it is impossible to reconcile their observed meanders with any map, no sufficient record of the geology can possibly be made.

The topographical work in the eastern field has been continued by the party under the charge of Assistant Charles Schenk. The work in this field was begun in April and continued until about November 1st, with the exception of an interval of seven weeks, when Mr. Schenk was detailed for certain special work to be described hereafter. Mr. Schenk has now nearly completed the map of the district lying between the Licking and the Kentucky rivers, from the mouth

of Slate Creek, on the former, to the mouth of Red River, on the latter, and extending back to Salyersville, on the Licking, and to Proctor, on the Three Forks of the Kentucky river. This district includes an exceedingly important coal and iron district, which only needs facilities for transportation in order to give it peculiar advantages for the production of these materials, and incidentally to stimulate important industries in the central agricultural district of the Commonwealth. Two sheets of the map of this district will be furnished for issue in the fifth volume of the reports, and the whole will, it is hoped, be completed during the present year. The country is, however, like all the border lands of the coal fields, somewhat difficult for topographical work. During the summer season the woods are exceedingly dense, making it very hard to run the lines of the streams, and in winter their beds are the seat of fierce torrents, which make it well nigh impossible to run transit lines through them. It is only by indefatigable labor that the assistant in charge of the party has been enabled to keep up an average of about three square miles per diem of field work. The reduction of this topographical work in the eastern and western fields will add about two thousand square miles to the area of the Commonwealth, when we shall possess topographical maps of an entirely trustworthy nature, sufficiently accurate to admit the representation of all necessary geological details.

In addition to the topography herein described, Assistant A. R. Crandall has made an important experiment in effecting a rapid topographical reconnoissance over a district lying between the border of the region traversed by Mr. Schenk and the head waters of the Kentucky river. Mr. Crandall's work was designed to furnish a basis for the recording of the exploration work done by him in this section of the State. This work of Mr. Crandall gives us a section of some hundred square miles, where the more important streams and roads are run by the compass and telemeter, carefully reduced and plotted by means of some ingenious inventions of his own,

the nature of which are set forth in the reports of the work which are to be published hereafter.

In the month of July I repaired to Cumberland Gap to take up again the geology of the very disturbed region near the boundary between Kentucky and Virginia. The region between this Gap and Pound or Boundary Gap, and for twenty or thirty miles west of the line connecting those points on the State line, has received the full effect of the Appalachian disturbances of an age later than the Carboniferous period. Faults and folds on a large scale have served greatly to complicate the geology of this district; and its generally wooded character makes the unraveling of these complications a matter of very great difficulty. Not much can be done in this work until a fairly good topographical map can be obtained; and my special object was to lay the foundations of such a work in this district.

The first thing to do was to determine with accuracy the position of the boundary line between the Commonwealths of Virginia and Kentucky. This line is by law made to follow the water-shed between the waters of the Cumberland and of the Tennessee. On the best existing maps of this country it is drawn as a nearly straight line for a good part of the distance between Cumberland Gap and Pound Gap; in fact, nothing could be further from the truth. The line is a continuity of very complicated curves, not being approximately straight for more than a mile or two in any part of its course. I have felt it to be very desirable to have this part of our frontier accurately surveyed, but have been hitherto deterred by the extreme difficulties of the problem. It is impossible to convey an adequate idea of the obstacles which beset such a work. The crest of the ridges which make this boundary are densely wooded, as is the whole of the district to the north of the line; on the south, in the valley of the Powell river, there is a country where perhaps one fourth of the land is cleared and tilled; but these openings, where they give a sight of the summit, are at the distance of two to six miles from its crest. Beyond the head waters of the Powell river the line runs along

the meanderings of a complicated ridge, rather flat-topped, and covered by an exceedingly dense, scrubby forest, with an interlacing undergrowth. It is very important that the positions along this line should be determined by some method of triangulation, a single transit line through a valley not being sufficiently accurate for the determination of so important a line in our State map.

It was decided to undertake, as an experiment, but a single section of this boundary in the year 1876, in order that, by the reduction of the results and the experience gained in the one section, any necessary changes could be made in the later stages of the work. To make this beginning, Mr. Charles Schenk was detached from his topographical work in Menifee county, and put in charge of this line survey. During the month of July and the first half of August, a chain triangulation was carried along, between Powell's Valley and the summit, in such fashion as to give the connection between the corner-stone, where Kentucky, Virginia, and Tennessee join at Cumberland Gap, and the break of the chain known as Pennington's Gap, at a point about forty miles to the northeast thereof. This work is now being reduced, and will give us a correction for the outline of the State, a part of its border which separates it from Virginia. It would be necessary, however, to determine astronomically the true position, or the latitude and longitude, of the line, in case we had to determine those elements at once. I hope to avoid this necessity by connecting this triangulation with that of the Coast Survey, and am promised this connection within a year or two. We shall then have a basis on which to rest our determinations of the geographical position of the southern and eastern lines of the State, which are probably miles away from the places they are given on our maps. Unless this line is now run, the area in square miles of the Commonwealth cannot be accurately determined. I am much inclined to think that it is considerably underestimated by the current accounts, which usually put it at about thirty-seven thousand square miles. It seems to me likely, that when we have the basis for

an accurate plotting of the State, it will be found to contain about fifteen hundred square miles more than this estimate allows.

In the previous reports of the Survey there has been frequent mention made of the triangulations of the Commonwealth, under the joint action of the United States Coast Survey and the Survey of Kentucky. There has been so general a discussion of the needs of such surveys in previous reports, that I shall not again set forth the important necessity of this work in our State. Suffice it to say, in a word, that anything like an accurate map of the Commonwealth—one that could serve as a basis for the organization of our industries and the representation of our resources—cannot be made until such a survey is extended over the Commonwealth. The necessary reduction in the general expenses of the Federal Government has somewhat limited the rate of extension of this work since its beginning in 1875; but an effective triangulation party has been in the field for five months in each of the past two years. The reconnoissance for the triangulation has been extended from Cumberland Gap to Danville, Kentucky; and it is now clear that an admirable set of lines can be carried from East Tennessee to Louisville, and along the tier of counties on the southern border of the State as far as the Tennessee river. From this main line of triangulation subordinate systems can be carried to all parts of the State. This will give the precise distance between each and every of some thousand points in the Commonwealth. The topographical work, carried on by the parties of the Survey, will fill in the gaps between these lines, and in time give us a detailed map of the Commonwealth. The special report of Assistant Page will set out clearly the condition and methods of this work at its present stage of advance.

I have now set forth the topographical labors of the Survey during the season of 1876. It will be found, on comparison of the plans laid out in the earlier reports, that some slight variations from the original projects of the Survey have been forced upon me. These variations have been brought about

by the progress of discovery within the districts where the work has been carried on. The work in the group of counties between the Kentucky and the Licking rivers has been carried further from the borders of the coal fields than was at first proposed. The original intention was to limit this work for the present to that part of the border which might be explored for a coal supply by the coal road from Mount Sterling eastward. The advance of the project of a railway extending eastwardly to Pound Gap, together with the important discoveries of mineral resources in this district, have served to make it plain that the immediate interests of the State required the rapid extension of topographical work in this district. In the same way experience has shown that the work of mapping in the western coal basin must be carried to its completion before the resources of this very important area can be adequately represented. The constant extension of our knowledge of its iron ores and coals has served to make it plain that the value of this district to the Commonwealth is almost inconceivable. At the same time, it is now clear that the extensive system of faults which exists in this district, and the peculiar localization of certain of its coals and ores, makes it necessary to have a detailed topography of the western coal field before it will be possible adequately to represent the limits and distribution of its several important sources of wealth.

In the plan laid out for the work of the Survey in the reports of the preceding years, it was stated that, except under the guidance of facts, the topographical work would, as far as possible, be limited to those districts of the State which might be adjacent to the existing transportation routes or those in process of actual construction. The experience of the Survey has driven me to the opinion that it will be desirable for the Commonwealth at once to determine whether it will continue its topographical work with a view to securing the construction of a detailed and trustworthy map of the State, or will abandon the effort to secure this most desirable record of its surface. As long as the topography of the Com-

monwealth is carried forward without the reasonable certainty of its completion, just so long will it be impossible to secure that degree of definiteness as to the object in view, which is indispensably necessary to the success of any important undertaking.

So far the topography of the Survey has been carried on with a double view: 1st. To the immediate production of trustworthy maps of certain important districts. 2d. To the future combination of these maps with other surveys intended to complete the topography of the Commonwealth. This work has already given us an accurate topography of about four thousand square miles of difficult country, at a cost of about four dollars per square mile for the field work, and about two dollars for the reduction and engraving of the same. With the experience already gained, I believe the cost of the work can be somewhat cheapened from these estimates.

I believe that a good working map of the Commonwealth can be prepared at a cost of about five dollars per square mile, not counting the money expended by the United States Coast Survey in making the triangulation of the country. This work will give the position of each dwelling, the directions and distances on the roads and streams, determined by transit and telometer, except the less important roads, which will be run by odometers. The heights would be approximately determined by lines of water levels and associated barometer work. The resulting map, though not up to the level of the great national maps of Switzerland or of parts of Germany, would afford a chart of the surface of the Commonwealth much more accurate than that now in the possession of any Commonwealth in this Union. Such a work would endure in its utility for perhaps a century to come, and richly repay the cost that would be incurred in its making. At a cost of ten thousand dollars per annum, the work could be completed in about fifteen years from the present time. As the work advanced from the more rugged mineral districts into the open country, it could be done with more rapidity and less expense, so that I feel reasonably sure that the total cost of a series of

very accurate maps, of the sort already undertaken in the work of the Survey, should not exceed the sum of one hundred and fifty thousand dollars, distributed over a period so great that the Commonwealth would not in the least feel the expenditure. Each year would, on the average, see about six counties provided with an accurate chart of their territories, so that the results would not have to be postponed to a remote future, but would be, from year to year, bearing their fruits.

Should this work be undertaken with a view to its completion, by means of a small annual grant, continuing until its close, the actual cost of the work would be much less than we should be forced to expend in the present temporizing policy. The collaborators in the work would not be forced to consider the likelihood of its being but a temporary occupation, having no certainty save from year to year.

RESULTS OF THE GENERAL GEOLOGICAL WORK OF THE YEAR 1876.

The work of this season, owing to the embarrassments caused by the Centennial Exhibition, has been less than in the season of 1875; nevertheless, it has not failed to give important contributions to our knowledge of the Commonwealth. The following are the most important results obtained during this season's campaign:

Assistant A. R. Crandall has been engaged in the work of extending his studies of the coal-bearing series between the further border of Menifee county and the head waters of the Kentucky and the Licking rivers. As will be seen from Mr. Crandall's report, to be published in the fifth volume of the present series of reports, an extensive and most important set of coals have been traced throughout this region, enabling it to rank in richness of stores with the measures of any district in the Ohio Valley. The analyses of Dr. Robert Peter make it plain that these coals have a singular freedom from ash, as well as from sulphur and phosphorus, giving them the first rank for that purity from foreign matters which is so important in the use of coals for smelting and gas purposes. The precise relations of these coals to those of the Greenup county

district has not yet been elaborated sufficiently to make it safe to pronounce as to their identity; but enough is known to warrant the assertion that the coals of that district are surpassed in excellence by those of the middle section of the eastern field. Although yet incomplete, I cannot but regard these discoveries as among the most important of those yet made by the Survey.

In this same field Assistant Philip N. Moore has carried to completion his studies on the Red River iron district, which he has fully described in his reports in the 2d volume of this series. It is to be hoped that this showing of the state of our iron industries in that very important district will serve to foster the creation of some system of transportation which will serve to render the resources of the district available. No other method of approach will do so much for this district as that which will be given by the improvement of the navigation of the Kentucky river to the Three Forks. By this improvement alone can we hope to secure to the noble furnaces of that district a full and cheap supply of varied ores of high grades, and, at the same time, cheap transportation of their products to the markets of the Ohio Valley.

Mr. Crandall has completed the section exhibiting the geological conditions of the region adjacent to the proposed and partly constructed line of railway from the Ohio river, at the mouth of the Big Sandy, to the central part of Kentucky. Besides the general interest of this route to the commercial interests of Kentucky, it has a very special value in reference to the iron production of the State, by giving a means of bringing the ores of the eastern border of the coal field to the furnaces of the Hanging Rock district along the Ohio river. Its completion would materially reduce the cost of producing iron throughout this district, and at the same time greatly extend the area over which the manufacture could be profitably undertaken.

The other work done in the eastern section was in the neighborhood of Cumberland Gap, and to the region to the northward thereof. The exceeding complication of the geol-

ogy in this district made it necessary to repeat certain parts of the work of last year before a sufficient certainty would be gained to warrant the publication of detailed sections. This repetition sufficiently assured the results to enable us to publish with confidence certain sections across the Cumberland synclinal from the State line to points west of the Pine Mountain. These sections will form parts of one of the forthcoming volumes of the Survey—probably of the fifth of the new series. While this detailed section work was in progress, Mr. Eugene Underwood was employed in securing certain lines of topographical survey; so that, while the basis for a complete map might be partly laid, there should also be some topographical foundation secured for the section work above referred to.

In the western field the geological work has made a considerable advance. Mr. P. N. Moore has been principally occupied in making a detailed study of the section between the Elizabethtown, Paducah and Southwestern Railway and the Ohio river. This work has been carried to completion, and the results may be awaited in the forthcoming reports of Mr. Moore. Although the same abundant iron ores have not been found in this region that were traced in the valley of Nolin river and Bear creek, to the southward, yet the coal field has been found to contain an abundant supply of good coals, and there are prospects of finding some of the iron ores in a fair state of development. The geology of this district has been more difficult to trace than that of most of the district bordering on Nolin river, on account of the considerable difference in the topography, which much less favors the exposure of good sections of the rocks. The reports on the geology of this district will be found in the forthcoming report of Assistant P. N. Moore; that on the topography, in the report of Assistant W. B. Page. These reports are to be printed in the fifth volume of the present series.

The interior part of this western coal basin has been continuously studied, during the present year, by Assistant C. J. Norwood, who has been put in general charge of its geology.

His work has mainly been limited to Ohio county, which presents an advantageous field for continuing the elaboration of the problems which have been taken up in the work upon the border of the field. Mr. Norwood has carried the work in this county to the point of completion which will enable us to give a complete geological report on its area. This has greatly extended our definite information concerning the distribution of the coal beds in the West Kentucky series, and enables us to re-assert that the classification of the beds of this district, made by my predecessor, the late Dr. David Dale Owen, was substantially correct.

This classification of the coals of this district had been brought into discredit by some ingenious criticisms of the State Geologist of Indiana, founded upon the sections shown on the Ohio river near Hawesville. As interpreted by Professor Cox, these beds seemed to show that Dr. Owen had much exaggerated the thickness, and consequent richness in coals, of this western coal basin. It will be seen, from the report of Mr. Norwood, that proof is now at hand proving that Dr. Owen was not in error on this point, and that the position of Professor Cox is not at all tenable. Mr. Norwood's report will be in press by the time this annual report is published, and will appear within six months thereafter. A suspension of judgment on this question is therefore asked until this answer to the criticisms of Dr. Cox can be made a part of the record.

In September, 1876, the Rev. H. Herzer was employed by the Survey to take charge of the work of collecting for the State Cabinet. Although a large collection has been accumulated, by the several officers of the Survey, in the ordinary course of their work in the field collections, of the highest value for the illustration of the resources of the State, it has seemed desirable to have some one person of special training employed continuously in the special work of gathering illustrations of the physical and organic history of the State. Mr. Herzer has had a long and valuable experience as a collector, and I doubt not that his services will prove an invaluable

means of extending our reconnoissance work, as well as of adding to the already valuable State Cabinet. Mr. Herzer has already made a tolerably exhaustive collection, within certain counties near the Louisville and Nashville Railway, where our detailed geological work has not yet begun. In his work, before the setting in of the rigorous winter of this unparalleled season, his collections of soils, rocks, ores, fossils, and antiquities have been sufficient to show that he can greatly extend an important branch of the work of the Survey.

In the last preceding report on the conduct of the Survey I inclined to suggest, as one of its important works, the making of a complete chemical study of the great geological section of the State, in order that each and every one of its various deposits might receive the light that can be thrown upon it by the chemist's inquiries alone. It is designed to connect this work as closely as possible with the organic and physical history of these deposits, so as to show, as far as may be, not only their constitution, but the origin of their several constituents. Some advance has been made in this work. Collecting has been instituted with special reference to its accomplishment, and, if circumstances favor, much can be done to urge it towards completion during the year 1877.

The work in the chemical laboratory is in part represented by the report by Dr. Robert Peter, in the fourth volume of reports, and in part by the several special memoirs contained in the second and sixth volumes. In the second volume is contained the admirable report on the chemistry of the hemp plant. This, together with previous memoirs on the chemistry of the tobacco plant, and other matters connected with those parts of the great field of agricultural chemistry, which especially concern our Commonwealth, constitute a very important series of contributions to our knowledge of this class of subjects, and should be taken from their scattered places in the several reports, and put into closer association in a single volume.

If the Survey is continued by legislative enactment beyond the year 1877, this assemblage of information in the agricul-

tural chemistry of the Commonwealth should be one of its special objects. By that time our work will have advanced to a sufficient degree to enable us to construct a soil map of the Commonwealth, and to indicate clearly the position of the several marls, limes, and other adjuncts of a well-conducted agriculture.

The experience of the Philadelphia Exhibition showed us clearly that the various plastic clays of the State were worthy of a more careful study than they have yet received. The conjunction of good clays and cheap fuel is all that is required to make the essential conditions of a successful manufacture of pottery ware. I am now satisfied that we have the essential conditions for this form of industry within our limits. Admirable clays abound in many parts of the State; fuel can be had for a little over one dollar per ton at points very close to the good working clays; excellent materials for building furnaces and making seggars, and the other necessary details of construction, are also abundant.

A careful study of these clays will require some years of inquiry; but as the industry is of the very first commercial importance, and brings an admirable class of workmen into any community, it will warrant a careful study of the possibilities of development in our territory.

I turn now to the consideration of the progress of the State Cabinet, a part of the permanent records of the Survey, to which the utmost importance should be attached. The value of such collections has its origin in a variety of needs which it is well to keep clearly before our minds. In the first place, these collections are originally, in part at least, the bases of the several geological reports that take their places in the records of the Survey. They should remain as the evidences of its work, and afford the means of reviewing its conclusions when, from time to time, it becomes well to submit them to such criticism. Not less important is their secondary use in serving as a means of conveying instruction concerning the resources of a Commonwealth. Many persons who cannot give the time to make a careful study of the written reports

of the several geological divisions of a large area, may still obtain valuable information, of the most trustworthy nature, by an examination of the specimens of a good cabinet, arranged so as to give a summary of all that is known concerning each county in the Commonwealth.

The quarters assigned to the State Cabinet, in the fire-proof building at the Capital, have the considerable advantage of security from the great dangers which menace most of our American collections of similar nature. They are, however, unfortunately, so limited in space that only a small part of the resources of the State can be brought into the Cabinet with any sufficient illustration. We are limited to about fifteen hundred square feet of floor surface, while the arrangement of the important specimens now on hand would occupy more than that area. The probabilities are, that the growth of the Cabinet during the coming year will be more rapid than during any previous year of the Survey work. I shall proceed with this system of collecting every thing that can aid in making at the Capital a well chosen and sufficient collection, illustrative of the physical structure and economic resources of the Commonwealth, trusting to the discretion of those charged with the custody of the property of the Commonwealth to provide a permanent and suitable place of deposit for these collections, at the proper time.

I have, in the Appendix to the first annual report of this series,* laid out a well-considered plan for an ideal museum for the illustration of our resources. This plan may have to be modified greatly, but it would be begun with a very small expenditure. A suitable building, of a sufficiently fire-proof construction, giving a ground floor of say eighty by forty feet, with one story of height above the basement, could be built for about thirty thousand dollars. In its construction the best building stones of our formations could be combined with our native woods, in such a way that every part of the structure would be representative of the resources of our country. The result would be the acquisition by the Commonwealth of a

* See this volume, page 25, *et seq.*

museum which would remain a permanent monument of its resources, and serve as a means of distributing accurate information concerning the same.

While suggesting some such eventual disposition of the valuable and growing collections of the Survey, the aim at present will be to secure the following system in the administration of these collections, which will be made to cover the following classes of objects:

1. *Mineral Resources.*—Coals, ores, building and other stones; pottery and other clays; salts and saline waters; coal oils and oil shales; specimens illustrating the economic treatment of these substances.

2. *Soil Resources.*—Soils, subsoils, &c.; marls; limestones suitable for fertilizing; specimens illustrating effects of different methods of economic treatment of the same.

3. *Natural and Artificial Products.*—Forest timber and other wild vegetable products; agricultural products, showing relation between the geological and chemical structure of soils and their products.

4. *Collections exhibiting the History of Vegetable, Animal, and Human Life within the Commonwealth.*—Flora of the State, recent and fossil; fauna, recent and fossil. Especial attention should be given to the problems of our caverns and our salt licks, which contain a great number of recent and fossil animals of the highest scientific interest.

The arrangement of these collections should, as far as possible, be made to show the following assemblages of facts: 1st. The resources of each geological formation within the State. 2d. The resources of each of its counties. To accomplish these objects, it will be necessary to have a printed catalogue of the collection, which shall guide the student in the search for these several different groups of specimens. It will not be possible, for instance, to have the objects from each county kept apart, as this would give a most undesirable scattering of the specimens that, for comparison, should be kept together; but, with a catalogue, it will be possible for the observer to trace the place on the shelves of the speci-

mens from each county, and to form an understanding of its resources.

Not the least important part of the administration of the State Cabinet should be the element of personal explanation, given freely to all who ask it. To make this effective, it will be necessary to have a well-trained keeper and an assistant constantly in charge of the collections, and accessible at all times to those who may desire information.

In directing especial attention to the desirability of a collection of this kind, I am by no means recommending an innovation. The States which have been most successful in the development of their resources have all recognized the formation of a sufficient cabinet as a most important step in bringing their resources into notice, and they have taken pains to connect therewith such skilled persons as might be necessary to afford advice and counsel to all who desired to avail themselves of its hidden wealth. In this manner they have given a living value to those elements of prosperity which are hidden from the passing eye, and are in a fashion dead until they are enlivened by intelligence.

The study of the forests of the State has been carried forward with considerable vigor during the past year. In previous reports I have discussed somewhat in detail the methods to be followed in these researches, and have therein indicated the principal points to be examined, with a view to the unraveling of their history and a complete ascertaining of their economic value.

The first report printed in the present series of reports concerns the forest growth in the northeastern counties of the Commonwealth. The second volume contains some other reports on the same subject, and yet other reports are in preparation concerning particular districts. With a view to hastening this work, Mr. L. H. DeFriese, a well-trained botanist, was employed during the past summer upon this class of problems. I deem it well to call especial attention to the important statements concerning the progressive replacement of our white oak forests, made in his report on the timbers of the

district lying on the eastern border of the western coal field, between the Louisville, Paducah and Southwestern Railroad and the Ohio river. Mr. DeFriese has shown that there is reason to believe that this change goes on apace, and that the replacement of the white oak by the black and red oaks is going on with such rapidity, that, within a century, unless some pains is taken to secure the planting of forests of this most valuable species, it may cease to furnish the basis for some very important industries which now quite depend upon it. Mr. DeFriese has also made a careful examination of the timber on the upper Cumberland, above Cumberland Ford. It is expected that the results of these studies will be printed in the fourth volume of the present series of reports. I hope that these studies on the timber resources of the State may soon be so far advanced that we may, by bringing these several studies together, be able to publish a volume on this subject, with a good map designed to illustrate the timber resources of the State, by giving the distribution and relative abundance of the several important economic species, together with such scientific results of our work on the forests, as may be pertinent to the question of tree culture and the preservation of forests.

A plan for the detailed studies, which will be necessary to give us a basis for the understanding of our forests, their climatal effects, their relation to the maintenance of an even flow of water in our streams, etc., has been drawn up, and is now in process of criticism and discussion. I hope, during the coming year, to have this sufficiently matured to put it before the government of the Commonwealth for their action. I cannot too often call attention to the momentous nature of all these questions that concern the relation of forests to the future usefulness of our streams, as well as to the general habitability of the land we are to give over to our descendants.

In the report for the year 1875, I have described the origin and nature of the relation established between the Geological Survey of Kentucky and the Harvard Summer School of

Geology. The beginning of this school was made possible by the cooperation of the Survey, which permitted the students to accompany its Assistants in their field studies, thereby enabling them to get that practical acquaintance with methods of field work which it is at once so difficult and important for the student to obtain. The second session of the school was also held within the limits of the Commonwealth, and the same relation to the Survey work was continued. No pecuniary expense on this account has been incurred by the Survey, and, in exchange for the incidental teaching afforded by its Assistants, a good many advantages have been secured to the Survey—not the least of which have been the establishment of the free intercourse with the trained men of science from other States, that is especially desirable to gentlemen composing the corps of the Survey engaged in the monotony of almost continued work in a narrow field.

The matters pertaining to the publications of the Survey have been subjects of anxious consideration during the whole year. The progress that has been made has been less than was expected at the time of writing of the last annual report. The Philadelphia Exhibition, by the requirements of labor which it laid upon the Geological Survey, retarded its printing work by nearly three quarters of a year, and diminished by one half the expected publications during the year. The following is a synopsis of the publication work done during the year 1876:

The first volume of reports of the new series, in octavo, containing seven reports on the economic results of the Survey, has been printed and distributed according to law. This volume contains over four hundred pages of text and about forty lithographic plates, some of large size. Of the second volume of reports, the 11th, or last part, was published and distributed at Philadelphia as a pamphlet. The remainder of the volume was stereotyped, and the plates, with few exceptions, prepared. The first three hundred pages of the third volume of reports were stereotyped, and a part of its plates prepared. A geological map of the State, representing the work to date,

has been compiled. This map was published in the part of the second volume that has been already issued, but will also be furnished separately.

The scientific results of the Survey, which have no immediate economic bearing, have been put into a series of quarto publications called Memoirs. Of these, the first volume has been stereotyped. It contains three hundred and fifty pages and about thirty plates. One hundred copies of this volume were printed for distribution at Philadelphia. The further publication of this very creditable volume awaits the action of the Legislature.

The Commonwealth at present owns the stereotype plates of about two thousand octavo and quarto pages, and the lithographic stones and photographic negatives of about two hundred plates and maps.

A series of one hundred views, of various parts of the Commonwealth, have been photographed by Mr. James Mullin, photographer of the Survey. These are to be issued, with an explanatory text, showing their position by reference to an accompanying map, together with the geological and other conditions of the district included in the field of view.

The work already done, and not yet carefully written up, will require about two thousand more pages of stereotype plates, and about one hundred and twenty-five lithographic and other plates for its complete record.

When the money necessary for the required work of stereotyping, printing, and engraving is deducted from the small appropriations of the Survey, the amount remaining applicable to field work is very small. Moreover, the laws regulating the conduct of the Survey require the distribution of the sixteen thousand dollars, available for other than publication purposes, over a very wide field of labor; topographical parties must be maintained in two districts; our varied economic resources have to be made the subjects of labor of specialists in the several fields; a chemical laboratory has to be maintained; various scientific problems inquired into; a Cabinet organized and kept in condition for instruction; a very heavy correspond-

ence has to be conducted—altogether requiring the services of at least ten assistants and aids; all for but one half more than the State of California pays the Director of its Survey for his personal compensation.

Nothing but the strictest economy, and the expenditure of considerable gratuitous labor on the part of those to whom the Commonwealth does not need to be indebted for self-sacrifices, has made it possible to continue this work in a decent fashion.

The plan of keeping the work of the Survey in a position to be understood by any person who may desire to acquaint himself with its operations, requires that I should set forth the project for the work of the Survey during the year 1877. Inasmuch as the expenditures of the Survey, during the year 1876, were so considerable as to encroach a good deal upon the appropriations of the following year, it will be necessary to limit the work to be done to rather narrow bounds.

The topographical work will be continued by a party operating in the western border of the western coal field, from the Ohio river southwardly. The effort will be to get the district between the Tradewater and the Tennessee rivers carefully mapped and prepared for the geological and other reports on its resources. A project for this work is now under discussion. The eastern field will receive some field work designed to carry further the mapping of the district lying between the Kentucky and the Licking rivers. Work on the central section will be begun by a careful survey of the county of Boyle. This last named work demands special explanations. I have indicated in former reports my sense of the desirableness of connecting the work of the Survey in as close a manner as possible with the learned institutions within the State. In several cases the Assistants of the Survey have been detached from its service for a part of the year, in order that they might be able to serve as teachers. The Harvard Summer School of Geology has been made possible by its relations to the Survey; so that, in this way, the Survey has done a great deal to secure the extension of those sciences on which its very exist-

ence depends. Over fifty teachers, and those expecting to become teachers, have learned their way to the study of nature from the officers of the Geological Survey of this Commonwealth; and in the future they will look to our fields for the basis of the work they are to do. I am happy to say that this effort to combine the work of the Survey with instruction, as far as it can be done without detriment to its immediate interests, will possibly receive an additional impetus from an arrangement which has been made with the Professors of two colleges within the State. Professors who are incumbents of their chairs are to have charge of the topographical work in certain districts; and their topographical parties will be formed from the more advanced students of the colleges, who propose giving themselves to pursuits which demand a knowledge of geology and field engineering. I have every confidence that this arrangement will give us good results at a less cost than they can be otherwise obtained. I shall be glad to make a similar arrangement with the other colleges of the State, so that, under the supervision of the chief topographer of the Survey, the greater part of its map work may be done by those who will get an intellectual profit from its labors.

An important work, interrupted by the demands of the Centennial Exhibition, will be resumed this year. I refer to the study of our streams with reference to the questions connected with the management of our rivers, and especially the regulation of their flow. It cannot be said too often that this Commonwealth is singularly dependent on the condition of her streams. For the transportation of the future products of her mines, fields, and forests; for the cheapest form of power for great industries; for the water supply of the growing cities within her bounds, she must look to her great system of rivers. Nor is it help alone that we have to expect from our streams. They may be the willing ministers of our needs, if we give them their fitting conditions, or they may become our masters and worst enemies. Thus, to a greater degree than any other State known to me, is our Commonwealth dependent on our

streams for her future. Every step forward in the study of their possibilities serves to make me the more sure that, unless they are cared for, there is no chance of securing the extension of wealth and population which is promised us by our resources. The proper discussion of the questions connected with the economy of our rivers will demand years of patient inquiry into the relations of our forests thereto, and the means of compensating for the necessary diminution of our woods with the increase of population. I am anxious to have the beginning of this inquiry made, though I believe it will be many years before the last word thereon can be said. Projects for the study of two matters pertaining to this subject have been already matured. One inquiry will concern the control of the floods in the region bordering the so-called Jackson Purchase, or the country between the Tennessee river and the Mississippi. This region owes its principal disadvantages to the fact that the belt of country lying between high and low water mark is very extensive, comprising a considerable part of the best lands of the district. These changes in the area occupied by the waters is damaging, through its restraining effects upon the cultivation of the land, and more seriously through the unhealthfulness of the climate which it brings about. If any way can be devised to keep the waters in the swamps at about the same level throughout the year, the experience of Holland and other regions which have conditions essentially similar to this lowland area, warrant the supposition that the danger from malaria would be removed. It is the variation in the level of the water, and not the area of swamp land, that causes those emanations that breed fevers. The other and closely related question in the economy of our rivers that demands our immediate attention, is that of the control of freshets which sweep their valleys, and are particularly destructive in the region above the mouth of the Tennessee. The inundations of the Mississippi come from so many streams that, for a great time to come, we can only hope to get any protection from their ravages through a system of levees. Those that sweep down the Ohio are largely derived from our

own rivers, and are to be controlled by yet other means. I have satisfied myself that these floods can be practically controlled by a system of very numerous small reservoirs along the small branches of our streams, which should hold back in some thousand ponds the waters which were once held by the matted vegetation of vanished forests, and by the innumerable beaver dams which had most important effects in regulating the flow of our rivers. I propose to bring this project to a careful discussion during the coming year.

The geological work of the Survey will be limited during the coming year to the completion of the Surveys already under way, and to the preparation of certain detailed studies on the mineral resources of the State. I am especially anxious to have a careful study made of the matter of washing and coking coals for use in iron manufacture. I am convinced, from the conditions of our Ohio Valley coals, that a great many of the beds which contain too much sulphur for use as raw coals, and yet have the other qualities necessary for this important application, can be made serviceable in metallurgical operations by some of the existing systems of deprivation.

Mr. P. N. Moore, who has been continuously in the service of the Survey since 1873, has applied for and received a leave of absence from its labors, which he proposes to use in informing himself of the possibilities of these processes, as shown in various works, where they have been applied, in this country and Europe. On his return, I hope we may have a basis in his observations for a careful study of this problem. If a satisfactory process of purification can be secured, I am inclined to believe that we shall make firm the basis for an extensive industry in the manufacture of the cheaper grades of iron in many parts of our State where it has not hitherto been deemed possible to undertake such enterprises.

In the first law establishing the second Survey, there is a provision, reaffirmed in subsequent enactments, requiring the publication of county reports, which should set forth in detail the resources of each of these political units of the Commonwealth. For manifest reasons, it was not deemed best to

undertake these reports until the general character and distribution of the resources of the State had been well studied.

We have now come to a point when we can take this work in hand. Reports on several counties are now in preparation. These on Menifee and Ohio counties are far advanced, and will be ready for publication during the present year. Without interrupting our other labors, it will be possible to furnish the reports on half a dozen other counties within eighteen months; and, as the work progresses, we will rapidly accumulate materials sufficient, with the cost of office work alone, to prepare careful accounts of each county. Judged by the work already done, these reports could be compressed within an average of fifty pages of letterpress of the size used in our reports. Each should be accompanied by a careful map, compiled from the records of the Survey, and to the proper succession, the various resources and conditions of the county should be set forth in all necessary detail. These reports will meet a need which cannot be met by any other system of publications; for it is the only way in which any ready access to the results of the Survey can be had by those who desire to inform themselves concerning their immediate surroundings. Besides the small gratuitous distribution provided for by our laws, the demand could be met by the sale of copies, at the average cost of about twenty cents for that of any one county. The work of making accurate sections along the several railway lines will be continued. The two railways that traverse the Western Kentucky coal field will have their sections, on which a certain amount of work has been done, carried to completion. I hope also to finish the lines of the Cincinnati Southern Railway, and possibly that along the line of the Louisville and Nashville Railway as well. These sections finished, it will be possible to furnish the person who traverses the State with a complete guide-book to its routes—one that will give, mile by mile, the geology traversed by him, and all the necessary details of information concerning the resources of the region accessible from any particular line.

I hope to continue the forest studies, which have been made in the work of the Survey, by some further explorations, directed as before, to the determination of the resources and prospects of the wooded districts, which still include largely over one half of the area of the Commonwealth. I hope to have this work next taken up in the district bordering on the Mississippi river, with the intention of having the cypress and other swamp and lowland timber taken into careful account. At present, less is known of these lowland districts than of any other part of the Commonwealth.

In closing the account of the work of the last year, I may say that, while the field labor and publication work has been restricted by the extended and imperative labors of the Centennial Exhibition, there is nothing to regret in its results. Work on certain parts of the Commonwealth has been prepared. The study of the Jackson Purchase district, which was assigned as a special work for the past year, has had to give way to the work of representing the resources of the Commonwealth at Philadelphia; and I consider the work of the Survey was delayed by about six months of time; but the advantages which we have gained through the causes of this delay will quite offset the evils of the retardation.

GEOLOGICAL SURVEY OF KENTUCKY.

N. S. SHALER, DIRECTOR.

THE TRANSPORTATION ROUTES OF KENTUCKY,

AND THEIR RELATION TO THE

ECONOMIC RESOURCES OF THE COMMONWEALTH

BY N. S. SHALER.

PART V. VOL. III. SECOND SERIES.

316, 317, & 318

THE TRANSPORTATION ROUTES OF KENTUCKY, AND THEIR RELATION TO THE ECONOMIC RESOURCES OF THE COMMONWEALTH.

In the matter of the economic development of the resources of any area, the means whereby these resources may be approached, and their distribution to markets accomplished, is often of far greater value than the character of the resources themselves. At first sight these questions of transportation would seem to be matters for the consideration of an engineer rather than a geologist, on account of the importance of the questions concerning the ease or possibility of particular projects; but the knowledge required for these considerations is, to a great extent, that which is obtained by the geologist rather than the engineer.

I have endeavored, as far as possible, to avoid the difficult considerations which arise from the discussion of the plans of several projectors of various transportation routes. The sketch given below is an effort to show what development of the existing lines of transportation is necessary to give the State a proper hold upon the economic resources found within its borders, and to bring them into relation with the rest of the world.

The first thing that strikes the observer who considers the transportation conditions of Kentucky, is the fact that the State is singularly isolated from the great markets of this continent. Its considerable railway system leads mainly to its local markets, and its wonderful water system lies undeveloped, or, when effective, is cut off, by some slight barriers, from access to its best mineral fields. In the past, this water system has been under grave disadvantages. Its ways, too, do not lead towards the great markets of the country. On the

contrary, they turn their course to the less settled sections, where development has not gone far enough to make great markets for the natural products of the State.

In considering the relation of natural and artificial ways to the markets, I shall take up first the rivers, and pass then to those channels of trade that do not depend, to the same extent, on the natural features of the country.

It is impossible to examine the rivers of Kentucky as I have done, during my journeys through the State, without being convinced that in them the Commonwealth has a wonderful set of natural ways whereby her great stores can be taken to their markets. In those ways lie her riches quite as much as in the coal, iron, salt, stone, oil, timber, and net products which are found beneath her surface. With all the grosser products of the earth the question of carriage must always be one of the first importance, and in the present and all prospective advance of rail transportation, the cost of carriage must always be much greater than by water, even where the latter form of transportation has to be obtained by locks and dams.

As previously noticed, our river system has had the grave disadvantage that it leads towards the west rather than the east. Such a river system turned towards the Atlantic coast would have made a very different economic history for this part of the continent. It should be noticed, however, that this disadvantage is, year by year, becoming less grave. The gain is made in two ways: firstly, by the increase in population in the regions bordering the Mississippi; and secondly, by the extension of navigation on these waters. There is, at least, twenty-five thousand miles of shore line on this water system that can be made readily accessible to water navigation. With the growth of population, it is not too much to expect that, within the knowledge of living men, this shore line will be occupied by a population of nearly one hundred million of people, with the most varied industries the world has ever seen gathered into one river valley. With this system of water transportation made completely available, Kentucky will always have the best possible chance of furnishing

a large share of the products of mining and manufactures used by the valley in which it lies. As regards the products of the earth found in this valley, she must always have the first place, as determined by the elements of richness and accessibility. Her coal, taking it for all qualities, is as good as that of West Virginia, and is far nearer the regions of great demand. She has the largest area of iron-working coals as yet discovered, and in many other elements of mineral wealth she is equally well favored.

It is not only in regard to the growing numbers and ripening civilization of the Mississippi Valley that this river system is of value. The civilization of Europe has overdrawn its stock of coal, iron, and timber, and the day has come when these must be brought, in part, from afar in order to maintain her industries. The Ohio Valley would, at present prices, be able to send iron to Europe at an advantage, if there were only a proper use made of these natural channels of trade. With the growth of capital and the adjustment of our currency, giving a sound basis for our industries, we may be sure of a vast source of wealth in this export alone. There is no other region in which can be found iron-working coal or cheap charcoal, together with iron ores of such varied qualities, all in such easy relations of distance to each other, and where their products are on a water system leading to so large a native and foreign population. Looking more closely to our Ohio river system, as developed within Kentucky, we are struck by the fact that the main river has very little actual contact with the best of the coal and iron of the State, or with that of the other States bordering on the river. In most cases these materials have to be brought to the river from some distance, either through its tributaries or by the means of railways. It is not necessary to discuss the reasons for this peculiar geographical relation of the natural resources of the valley. I only wish to call attention to the fact that there is less good coal on the Ohio river front than on any one of its principal southern tributaries, and that the peculiar difficulties which beset the approach to these fields are common to the whole

river. That these difficulties of position are not at all serious, is shown by the fact that they are obviated not only in many other countries, but that the most prosperous coal mining region on the Ohio, that of the Monongahela river, is approached by means of locks and dams, there being already several of these structures, giving about one hundred miles of navigation on that river. What is especially desirable in Kentucky, is the careful prosecution of the work of improving the navigation of the rivers of the State by means of locks and dams, as has often been proposed. In the Appendix to this report, I have assembled the information which I have been able to gather concerning the results obtained by the special surveys made about forty years ago, with the view to this sort of improvement. This work was begun about fifty years too soon —before the demand for the mineral products of the State had grown to sufficient dimensions. Its advantages would have been great, however, provided that in any one of the easternmost streams of the State these improvements had been carried to completion; as it is, the half success of the experiment on Green river has counted against the work. A glance at the map will show that the mouth of this river is below all the more populous cities of the Ohio Valley, it being necessary to tow the boats, carrying coal and other similar products, up the river for a great distance, in order to find any considerable market. If this improvement had been applied to the Big Sandy, the Licking, or the Kentucky, the markets of Cincinnati and Louisville would have been opened to its products. The improvements on the Green river are gradually growing in value, and I look forward to seeing them extended so as to give access to the admirable coal and iron deposits on its tributaries—Mud river, Bear creek, and Nolin river. The markets below its mouth, though still small and suffering from the great depression arising from the late war, are slowly coming to their natural prosperity. The unhappy and utterly unnecessary blunder which was made with the first furnace in this valley, that at Airdrie, has done a great deal to frighten capital away from this region. The cause of this unfortunate piece

of mismanagement is well set forth in the report of Assistant P. N. Moore, in the second volume of this series of reports. After a careful personal study of the conditions in this valley, I am satisfied that, with the revival of industry, which all reasonable men await, this section is sure of a prosperous industry in iron manufacturing. I am convinced that, reckoning the cost of getting the product to a great market as part of the cost of manufacture, there is no region in the world where iron can, at the present time, be made any cheaper than it can here.

To complete the navigation of the Green there is needed an extension of the slack-water to Nolin river, and up that river and up Bear creek for about twenty miles on each. One dam will answer every purpose on the main river, and one on each of these tributaries. Or it may be, that, by making the dam on the main river rather high, it would back up those streams for a sufficient distance for all the present needs of access to their ores. The navigation on Pond river should be extended by one more dam, to give access to the admirable ores on that stream, which, with this improvement, could be shipped, at a good profit, even as far as Cincinnati, whenever the manufacture of pig iron becomes again active. With these additions, which could all be made for less than two hundred thousand dollars, I should regard this stream as having all its known resources sufficiently opened to industry.

The Cumberland and the Tennessee are so far within other States that the plans for the bettering of their navigation should be accomplished by the General Government. The resources which will be brought out through their improved channels are really enormous, and though not in the main from beneath Kentucky soil, would still serve to build up the interests of the Ohio Valley, in which Kentucky has the largest share of any State. The Cumberland is more the property of Kentucky than the Tennessee, for the larger part of its course is in our State. The region drained by its upper waters has a great store of coal, and is especially rich in the

heavy lubricating coal oils, which are sure to have a large and constantly increasing market.

The small, narrow, and crooked stream bearing the name of the Tradewater river, has not yet been sufficiently explored. Its banks are very richly stored with timber, and there is, doubtless, much coal accessible on its waters. A preliminary study of its drainage goes to show that one or two dams will develop a great deal of navigable water. These dams would be low and of small cost. Probably, with sufficient accommodation for boats of a size fitted to pass the narrow and tortuous windings of the stream, thirty thousand dollars each would be a sufficient estimate. I base this reckoning on similar works in other districts.

Above the Green, there is no river which demands improvement, in the interests of the mineral resources of the State, until we come to the finest of our purely Kentucky rivers, the noble stream of that name. In the old work of improvement of the rivers, this stream had four locks and dams, of good workmanship, built along its course. Of these, the uppermost was just sufficient to carry the navigation to Hickman Landing, above Frankfort—still about one hundred miles below the lowest coal and iron on its waters—practically not in the least bettering the mineral interests of that valley, though it has well paid for itself by its incidental effects on the prosperity of the Commonwealth. To complete this system, there should be about twelve more dams on the main stream, carrying the navigation about one hundred and fifty miles further up than it extends at present. Then a system of smaller dams on the tributaries—giving about three to Red river and four each to the North and Middle Forks—would make an effective outlet for the resources of a large area. At the time of the surveys for these improvements, it was proposed to make a water route to Cumberland Gap, by building a dam at Cumberland Ford, taking the water thence, by canal, to Richland creek, entering the same at a point about six miles above Barbourville; thence, by a cut about a mile in length, and not over forty feet deep at any one point, to Colline Fork of

Goose creek; thence down Goose creek to the Kentucky river, a total descent of two hundred and twenty-five feet, requiring about thirty locks for the connection between the Cumberland and main Kentucky. Yellow Creek, above the Cumberland Ford, would give, with two locks, an easy passage up to the foot of the Cumberland Gap, within about a mile of the summit of the pass over the mountain. This would make a total of about forty locks between the Cumberland Mountain and the Ohio river. The cost of the work would require reëstimation for modern prices. A careful consideration of the Kentucky river has satisfied me that the lockage could be finished to the Three Forks for about two million of dollars. On the tributaries the locks and dams would cost about fifty thousand dollars apiece, so that Red river, and the North and Middle Forks, would, for the locks we have proposed, cost about five hundred thousand dollars. If it was ever desired to carry out the project of a canal to the upper Cumberland, the cost would be about three million dollars for that work alone—a cost that makes it inexpedient to consider it at present. I must say, however, that this last named channel offers certain great advantages. It will be seen, by reference to the preceding reports in this volume, that the iron ores at the Cumberland Mountain are the cheapest and best of any within our limits or near our borders. It is exceedingly desirable that they should be brought into close relation with our iron ores and iron-working coals. I believe in time our industries will warrant the investment of the money necessary to make this line of cheap water transportation; for it will serve to bring the question of carriage of ores in this great ore and coal district to a most satisfactory solution.

I am satisfied, that if the slack-water navigation of the Kentucky river was carried up to the Three Forks, it would be rapidly extended up the smaller tributaries. The cost of the locks and dams in the smaller tributaries is much less than in the large streams. Sufficient locks and dams on the Three Forks of the Kentucky will cost only about one half what would be required on the main stream, and the rate of

fall would give something like three fourths of the navigation to each lock that it would in the main stream. As will be shown hereafter, the expense would be but little more per mile of navigable water than the cost of the turnpikes, and not over one third the first cost of cheap railways. When the navigation of the Kentucky is fully developed, it will afford about six hundred miles of navigable water bordered by coal, iron, salt, and timber lands. Every dam will be a possible source of water-power; for the flow is much in excess of the probable needs for lockage. The cost of this navigation will probably be not far from five thousand dollars per mile, unless done by convict labor, when it can be reduced to about three thousand dollars per mile; in the one case the total would be three millions, in the other, twelve hundred thousand dollars.

The next stream, the Licking, has not quite half the possible mileage that we find on the Kentucky, and the cost of getting to the point where the coal field begins would be about twice as great. At least twenty dams would be required to take the navigation to that point where the supply of iron ore becomes great. If we had them now, there is no doubt that there would be a great tide of trade poured over this way. It gives access to some admirable iron ores, which, by slack-water navigation, could be put at the furnaces in Newport so as to cost, for the ore required to make a ton of pig metal, not more than five dollars. Its admirable cannel and bituminous coals should find a great market in the Cincinnati centre, where the stream debouches. This stream, with the safe harborage for vessels, and its ready access to the greatest city of the Ohio Valley, would become a great manufacturing centre. Four of these locks and dams were begun, but only one, the lock No. 3 from the mouth, has been kept uninjured; the others have been destroyed to the foundations for their stone. The dams in this river would be less costly than on the Kentucky, especially if the plan of beginning the dams at the head waters and working down was adopted. Some time would be lost, but admirable building

stone would be secured at low cost. Reckoning from the contract prices of dams on the Monongahela, we may estimate the cost of locks and dams on the Licking sufficient to carry the navigation to West Liberty, at about two million five hundred thousand dollars, with ordinary labor. Many of the lateral streams are worthy of improvement by one or two dams—Slate creek, in order to give access to the Preston ore banks, and the coal nearest to the lower river, and other streams to give more coal frontage. The total possible navigation in the coal and iron district on this river is about one hundred and eighty to two hundred miles. Owing to the smaller water supply, the water-powers would be less valuable than on the Kentucky river.

Still further up the Ohio river we have Tygert's creek and Little Sandy. Both these streams are capable of this form of improvement; but the Little Sandy is sufficiently improved by the railway which traverses its valley, which was built for the purpose of furnishing an outlet for the mineral wealth of the district. Tygert's creek, though a smaller stream, is quite capable of being locked and dammed at relatively small cost. It would open a considerable territory for coal and iron production. The Lambert ore bank, and other ores found along its waters, would furnish cheap shipping ores. To carry this navigation to the Iron Hills Furnace would require about six dams, costing about two hundred thousand dollars, if made with locks for sixty-foot boats, which are large enough for this rather crooked and small stream. This stream would furnish the most westerly coal on the main Ohio above its principal cities.

The Chatterawha or Big Sandy river is admirably suited for this form of improvement. On its waters we have a great series of coal seams; in fact, the most westerly development of the beds certainly identifiable as the West Virginia and Pennsylvania seams, is found on its eastern branch, the Tug Fork. Six dams on the main stream and two on Tug Fork would cost less than a million dollars, and would give about one hundred miles of navigation in a good coal country. Ex-

cept the recently discovered "black band ore," the only valuable iron ores known to this Survey on its waters are on the tributaries of Big Blaine creek, which it would be possible to lock and dam by making storage reservoirs. Every mile of the possibly navigable waters of this stream abounds in coal of varied qualities. The stream is strong-flowing in the greatest droughts, and would afford excellent water-powers at all the main dams. The navigation could be extended up the smaller streams at many points. Big Blaine, Rockcastle, John's creek, Beaver creek, are all suited for such improvements, and on the main stream the system would be possible quite up to the State line. The possible water transportation on this river, which would be regarded as within the mineral belt, amounts to quite four hundred miles.

I am glad to say that there is a chance of action on the part of the Federal Government looking to the improvement of this stream. In 1875 I furnished, at the request of the United States engineers, a report on the mineral resources of this district, with special reference to this matter of slack-water navigation in the Chatterawha or Big Sandy Valley. As a good part of the waters of the river lies within the boundaries of another State, the Federal Government has a warrant for an effort at its betterment, and our Representatives should urge action on this point with all possible energy. With the same number of locks and dams on this river that has been built on the Youghiogheny, it would be possible to put equally as good qualities of coal into the Ohio below all the most serious dangers of navigation that menace the coals moving from Pittsburg to the lower Ohio, thus bringing the eastern coal beds of the Commonwealth at least one half nearer the market than the present sources of supply. The Peach Orchard coal brings the highest price paid for bituminous coal, and regularly sells at better prices than the Pittsburg coal, whenever it manages to struggle past the obstacles which block it from the market.

The upper Cumberland, within the limits of Kentucky, affords over three hundred miles of waters which could readily

be made navigable by slack-water but for the eighty feet of fall and some distance of cascades, where it passes the conglomerate of the coal measures. The fifty miles of this stream below the falls only afford a precarious navigation to small steamboats—a navigation which is so little to be trusted, that it cannot be thought of much value. Excepting at the falls and rapids above described, the Cumberland is a stream of very gradual fall, and is, therefore, well fitted for improvements of this description. Engineering skill would doubtless succeed in contriving a canal past these obstructions without great difficulty. The tributaries of the Cumberland, on account of their gradual fall, are peculiarly suited for the ready creation of a great canal system. Big South Fork, Laurel river, Clear Fork, Big Yellow creek, Straight creek, and the uppermost head waters, Poor Fork, Clear Fork, and Martin's creek, are capable of transformation into cheap canals.

The upper Cumberland, within Kentucky, can readily furnish six hundred miles of very important navigable waters. Thus we see that, including Green river and its tributaries, the Tradewater, the Kentucky, the Licking, Tygert's creek, the Chatterawha or Big Sandy, and the Upper Cumberland, the State can readily secure enduring water navigation having a length,within the mineral districts,of about twenty-four hundred miles. Estimating the average length of the pools at ten miles, would give a total of two hundred and fifty dams; and these, at a cost of say fifty thousand dollars each, which, inasmuch as the small tributary dams are small and not costly, is, it seems to me, a sufficient average price, we have a total of about twelve million dollars for the total cost. When we compare this sum with the cost of creating other practicable ways for the transportation of heavy materials, it is seen to be by no means excessive. The cheapest railways, fitted for heavy traffic in coal and iron, cost nearly ten times as much per mile. Indeed, the cost of this form of canal is not much over the cost of good ordinary turnpikes. The cost of operating is not to be compared with that of railways, nor even with turnpikes of the first class. The cost of the force of propulsion,

and the consequent impost on the materials, is exceedingly small compared with railways. This, with coal and iron, in a region where the transportation makes all the difference between profit and loss, is a most important matter.

The cost of creating this system of water navigation may be materially reduced by using convict labor, and protracting the work long enough to accomplish it in this fashion. Supposing the labor of seven hundred and fifty convicts is given to the work, and supposing that two thirds of the cost of construction is in the labor, it would require about forty years to complete this system, which is not too long a time for the execution of a great system of public works of this kind. If undertaken at once and steadfastly prosecuted, by the expiration of that time our State would have a system for the production and cheap transportation of iron and its products which would be without rival in the world. It would not require more than two hundred thousand dollars per annum, with the convict labor, to bring this scheme to completion; so that eight million of dollars, spread over nearly half a century, and giving, as one of its benefits, the incalculable amelioration of our penitentiary system, is the small price we would have to pay for this noble system of ways to our wealth.

In any contemplated extension of this slack-water system in our State, I would suggest a careful inquiry into the several methods of making dams now used in Europe. One of these methods, the system adopted to some extent in France, uses a dam that can be lowered down in high water and lifted in low water, with great ease, and possesses many advantages, inasmuch as it does not obstruct navigation in high water, permitting vessels to run out in floods without the delay of lockage, and yet providing locks when they are needed.

Another plan, which will be found very useful on the small creeks, tributary to the Ohio and to the Kentucky streams, where there is already slack-water, or where it may be hereafter built, has for its characteristic feature a contrivance whereby the lock is entirely dispensed with, and only a few hundred gallons of water is necessary to pass a vessel one hundred

feet long and twenty feet wide. An inclined plane, made of wood, leads from below the dam to its crest, rising at the rate of about two feet in a hundred. This can be made slippery by allowing a little water to flow over it, and then the boat mounting is dragged up by oxen. In descending, the vessel runs down the slope unaided, like a launching ship. The advantage is not only in the saving of water, but in the less cost of the inclined way as compared with the lock, it being readily seen that, in a country where timber abounds, the cost of the way need not be over five thousand dollars, even when built in the most solid fashion. The only place where I have seen these dams is in the Saltzkammer-gut, or the crown salt lands of Austria, where it is extensively used for the transportation of salt to market, the return loads being very small. The increased cost of return loads comes from the need of oxen to drag the boats over the dam. It would be easy, where there was a reasonable supply of water, to make a small water-wheel do this work. A wheel costing only a few hundred dollars would furnish ample power for the needs of this work. From what I have seen and heard of this method, I am inclined to think that it might work as well on the main streams as it does on the smaller rivers of Austria, where it has been adopted on account of the saving of water. If this should appear, on careful inquiry, to be the case, it would be immensely to the advantage of the general plan; for it would greatly reduce the expense of construction and management. On the main streams, where most of the transportation would be done by means of steamers towing flats, the steam power of the tug-boats could be made to drag their barges over the dam. The most considerable advantage of this system would be found in the fewer dams required, and the saving of all the trouble incident to the maintenance of locks. In order to carry vessels of large burden, there must be at least four feet of water on the gate-sills of the locks. This amount of water can often be readily had in mid-stream, five hundred feet below the lock, when it is hard to get it on the lock floor, and the water-way leading thereto. Some damage

would naturally be apprehended from the straining of vessels in passing over such ways. I believe that this fear is groundless; or, if it should prove an obstacle, it would be easy to meet the difficulty by the use of sheet-iron boats, which are pronounced to be the cheapest for long-continued usage. If this plan can be adopted for streams of all sizes, it would probably reduce the cost of giving our rivers the advantages of a system of locks and dams to not more than two thirds the cost of the ordinary method; possibly even less, for it is the locks, rather than the dams, that will make the expense of this form of navigation on our narrow rivers.

Inasmuch as this question is one of national importance, the Federal Government might be memorialized to have the whole question adequately examined, and determinative experiments made. By some such means the Ohio river could have its completely navigable waters extended to over six thousand miles of length. The problem of cheap transportation can be more easily solved in this way than any other.

Even where it is not deemed advisable to improve the whole of a river, it will sometimes prove important to make this form of navigation connect with a railway system. When the Chesapeake and Ohio Railway is extended to Lexington, Kentucky, as it must be in time, the Licking, from the crossing of the railway to its head waters, should be provided with these locks and dams, or locks and slides. At a cost of something like five or ten thousand dollars per mile, this river could be made an admirable branch line of transportation for the railway. For this end, if desired, cars could be taken directly on to the boats and loaded at the mines, and taken from the boats, by an inclined way, to the main railway. The upper Cumberland, when it is crossed by a railway, either at the ford or at the falls, could be treated in a similar manner. My opinion is, however, clearly to the effect that the State should start with the determination to make, in time, every bit of possibly navigable water within its mineral districts the seat of actual navigation, so that its great natural sources of wealth may suffer no hindrance from the evils which so generally cramp the development of such resources. In the great race which is before our Ohio Valley States it will secure her the victory.

RAILWAY TRANSPORTATION.

The advantages of our natural water-ways have been considered in some detail. It will be seen that the possibly navigable waters intersect the State so completely that there is no point more than twenty-five miles from water which could be made passable for boats carrying one hundred and fifty tons of coal or other equal burden. But, as before remarked, all this system turns its current towards the west; and it is only through the Mississippi river, or the eastward-running canals, that water-ways can be had towards the great markets of the world. Year by year, with the marvelous growth of the Ohio Valley, makes the products of its tributary streams more valuable. But it is, in a high degree, important that in this growth our State should have its full share of the increasing markets. That it has failed to get this share in the past cannot be questioned. The first State of the Ohio Valley, in order of time and in order of resources, she has been the last in order of growth. The reason for this is plain. The other States, from the Gulf to Canada, have had their ways leading to the east, whence has come the tide of immigrating capital and labor—ways of water and of iron—the best that art could build. Kentucky has had the Wilderness Turnpike, a way where the tolls are about the only evidence of the existence of a road. It is easier for the immigrant to find his way to Kansas than it is to Kentucky; and it is not surprising if he concludes that the region must have little to offer where there are so many obstacles in the way of access. We have permitted the great store of coal and iron, which forms the so-called mountains of the State, to serve as an unbroken barrier between us and the outer world, cutting us off from the great cities of the Atlantic seaboard, from the Southern and Eastern States, and from the European markets.

It should be the especial object of our railroads to open the east to our markets, as our improved rivers will open the west. I shall not consider the existing railroads of Kentucky, nor those required for other than mineral purposes, but shall limit myself to the main lines necessary for the fullest development of our industries which have a geological aspect.

The so-called mountains of Kentucky, so far from being a barrier to the passage of railways, is, on the whole, a region more fitted for their passage than the Blue Grass country. The valleys are more traversable, and the great obstacles more easily turned. The cost of trunk roads to the sea should be less than an equal mileage in Central Kentucky, constructed with the same thoroughness. In this I am expressing the opinion of competent engineers, who have examined the country with preliminary surveys, whose judgments my own observations have abundantly confirmed. In the present condition of capital in Kentucky, and with the limitation of our Constitution, it is absolutely necessary that the greater part of means of construction of these roads should come from other States. In this regard the position of Kentucky, with respect to the bordering States, is, on some accounts, fortunate, and in others unfortunate. The mother State on the east, Virginia, ravaged by war, worn by time, and robbed of her richest lands, can give us little but good will as aid. The West Virginia section is helpless from several causes, as well as from the doubt that rests on the legality of its organization. The States of North and South Carolina are also in grievous financial trouble. All these States, however, have a material interest in getting highways through Kentucky, and whatever can be done by them will doubtless be done in aid of this work. It is, however, to ourselves, and to the States to the north and west, that we must look for the execution of these great works. The need of coöperation, and the chance of obtaining it, will necessarily greatly influence our plans of breaking through our eastern barriers. The same causes which led to the creation of the Cincinnati Southern Railway will, in time, force other lines through the State. My

aim is simply to show the points at which this barrier can best be broken by railways, both as regards the physical and mineral conditions of the routes.

Beginning at the Ohio river, the first of these routes is that which has been projected, and a small part actually built, along the Ohio river, following the meanders of the stream, from the mouth of the Chatterawha or Big Sandy to the city of Newport. This road, while promising many eminent advantages, would not serve as a main eastern outlet for the body of the Commonwealth. Its principal mineral value would be the certain market for the products of the mines and furnaces approached by the Eastern Kentucky Railway—already one of the considerable roads of the State. Coal that has once been placed on rail cars should not be transferred to boats on account of damage of transfer. As these coals, or, at least, that of the most worked seam, have peculiar properties of great value as coals for smelting iron and for locomotive boilers, they would command an extensive market. The iron ores of this region have also some peculiar properties, which may well bring about their shipment to other iron-producing districts in the Ohio Valley. The shipment of coal to the Cincinnati centre from these Eastern Kentucky mines would, doubtless, make this region one of the sources of supply for that great market. I do not believe it could compete with the supply from the Big Sandy, when that river has been provided with proper locks and dams for the lower one hundred miles of its course. When that is done, shipments by rail to the towns as distant as Cincinnati will, for the ordinary uses of house and steam coal, have to be limited to those seasons when the main river is unnavigable, and the price of coal consequently much enhanced. Probably the greatest advantage that could be gained by this road is in the better chance it would afford of marketing our Kentucky iron products in the middle Atlantic States. This, however, will be substantially gained by any connection between the Eastern Kentucky Railway and the Chesapeake and Ohio Railway. There is no question that this railroad will be required by the com-

Gap. These ores can be put at the Red River furnaces for about two dollars per ton; so that four dollars' worth of ore will make a ton of pig iron. It will, at the same time, give an outlet for the product of these furnaces. One and a half million dollars have been invested in these furnaces, but they are now lying idle for lack of sufficient transportation to furnish them with ores and take away their product. These furnaces could be operated to-day at a profit if this railway were in existence. The Manchester Salt-works are apparently capable of indefinite extension in their production, provided they were supplied with cheap transportation. At present, their product struggles out over almost impassable roads into East Tennessee and Central Kentucky. The iron ores of the neighborhood of Cumberland Gap have already been described in the preceding section of this report, and in the more detailed report of Mr. P. N. Moore. To give a chance for this interest to develop itself—to build in our borders, as we certainly should, one of the most extensive iron industries in this country—would be of itself a sufficient result of this road to pay for its building many times over. The variety of coals accessible on the line of this road, or any similar line, is great. Details on this point will be found in the special report* concerning the line from Livingston to the Gap. In this report will be found a discussion of these cannel coals, and the other geological features of this line.

The great importance of this line cannot be presented without considering its relations beyond the limits of the State of Kentucky. It is as a through line from the northwest to the southeast that it most deserves our attention. The proposed Chicago and Southeastern road would most satisfactorily establish the relations which would give this line from Central Kentucky its true character. Passing through Kentucky, on the shortest line, this road would come by Livingston Station, or some line near there. But this line would not serve the purpose of continuing the Kentucky

*On the line from Livingston to Cumberland Gap, by C. J. Norwood, volume II, second series.

Central Railway which is one of the improvements the near future must bring into existence; nor of furnishing connection to the Red River furnaces with their markets, on the one hand, and new supplies of ore on the other. It seems to me, that the best plan would be to carry separate roads from Livingston and from Red river to some point near Cumberland Ford, and make them joint roads from that point eastward to the Morristown (Tennessee) connection with the southern and eastern railroads. With this set of roads from the Gap, westward and eastward, we would develop a very extensive coal and timber country, opening at either end to good markets. On the west, they would ship coal through Kentucky to the Ohio river; on the east, the whole of the market of the Carolinas and East Tennessee would be within the range of competition. It will be seen, by a glance at the maps which accompany this report, that the three eastward connections provided by the roads which are advocated here would, in fact, be the through routes to the sea-board, each terminating at one or more of the first-class harbors of our coast: the Lexington and Big Sandy connecting advantageously with New York, Philadelphia, Baltimore, Washington, Alexandria, and Richmond; the Pound Gap road would give direct connection with Norfolk and Wilmington, North Carolina, by a nearly air-line route; the Cumberland Gap affords a direct connection with Charleston, South Carolina, and Savannah, so that our principal mineral belt would be brought into the most immediate contact with all the shore-belt cities of the Atlantic for a hundred miles of coast. The coaling of the ocean navigation steamers, which, in fifty years, will go forth from these cities, between Washington and Florida, would of itself develop the mining interests of Eastern Kentucky. These Kentucky mines can put coal in Norfolk cheaper than it can be had from any other region, owing to the fact that they can be worked without pumping, and deliver their coal directly on the tracks of the railways.

These three trunk lines, with their connections, giving three new channels to the east, can be made by building four hund-

red and ten miles of road, which, at the average of thirty-five thousand dollars per mile, aggregates thirteen millions of dollars. Taking only the Big Sandy and the Cumberland Gap lines, which are the most important to the State, from the point of view of its mineral resources, the expense need not exceed six million dollars to secure connections with Huntingdon and Morristown from the Mount Sterling and Livingston termini.

For the present, I should feel that it was safe to trust the development of the Kentucky River Valley to its slack-water navigation, if that should be improved, waiting until the future for other communications; but in the case of the roads from Livingston to the Gap, from Winchester or Mount Sterling to the Gap, and from Mount Sterling to Huntingdon, I feel that they are the most pressing of all the imminent needs of our State, and the very first condition of her future prosperity. The cost of their building will not begin to equal the expenditure of money incurred in making any other of the great east and west routes of this country. It seems to me that they cannot fail to pay a sufficient return on the capital expended in their construction. I do not know of an instance where a road, passing for its whole distance through a valuable coal, iron, and timber district, and at the same time a district of fair agricultural qualities, connecting at either end with a far-extending ramification of routes with first-rate regions, rich in other resources, but wanting in mineral and timber products, has failed to pay.

In the three lines indicated in the foregoing discussion of the important eastward routes north of Cumberland Gap, I have desired to do nothing more than refer to the facts which are discussed in an elaborate manner in the special reports of the officers of the Survey concerning these lines of possible railway. The last part of this discussion I will give to the consideration of a line which has not yet been fully explored, but which deserves to be regarded as one of the most important ways for the development of the State. A glance at the map will show that none of these ways provide access to the

region immediately bordering the Tennessee line. It will at the same time be seen that a line passing in the most direct fashion from the great geographical centre of the Mississippi Valley, the junction of the Ohio and Mississippi, in the most direct way, to the southeastern seaboard, is a matter of great importance, not only to the State of Kentucky, but also to the whole Mississippi Valley. Taking the line of the Elizabethtown and Paducah road, from Paducah to a point near Caneyville; thence by the most direct line, past the Mammoth Cave to Glasgow Junction, on the Louisville and Nashville Railway; thence, by way of Monticello to Barbourville, we find that a total additional iron way of about one hundred and eighty miles would bring this road into connection with the other proposed roads to Cumberland Gap and the eastward. This line would give a connection between St. Louis and the sea about one hundred miles shorter than any existing route. But it is not the shortness of the line alone, and the consequent easier passage between the heart of the Mississippi Valley and the sea-board that commends it. It is the fact that it traverses, at their greatest breadth, the two principal coal and iron fields of our State. More than three hundred miles of this line would lie within the coal and iron belt, not over one third of its length within our borders being destitute of these advantages. No other road to the eastward from the Mississippi will have anything like the same amount of coal and iron on its line.

In the section east of the Cumberland there is a great area of beds, affording lubricating oil of the most admirable quality, and which, at present, struggles to a market over thirty miles of bad roads and one hundred miles of difficult river navigation. I see no reason to limit these coal oil-bearing beds to narrow bounds; and the conditions favor shipment to the eastern ports.

At the crossing with the Louisville and Nashville, the Cumberland and Ohio, and the Cincinnati Southern, this road would find a great market for the coal that is found along its line. To the Nashville line it would afford a pas-

sage to the Mammoth Cave, and thereby obtain the large passenger trade that now passes to that point. At its crossing over the Big South Fork of the Cumberland it would come upon about the best water-power in Kentucky. This crossing point could not fail to grow to be a seat of a great manufacturing industry. Rich and varied as is the timber supply of the rest of the State, this line would command the richest and most varied resources of that kind known to me in America. Along the whole line the hard-wood timbers abound. The whole western coal field is one nearly unbroken area of hard-wood forests of the finest quality. East of the Louisville and Nashville Railroad there is a great amount of fine cedar timber. At the crossing of the Big South Fork we get a water-way reaching far up into the Central Tennessee table-land, rich in the several varieties of soft wood or coniferous timber which belongs in this valley. The agricultural capacity of this line will be, on the average, greater than on any other line of equal length known to me in this country, when we take the variety and value of its crops into consideration. The whole of the line is an admirable fruit region. Damage by frost is exceedingly rare—fruits ripening earlier by some weeks than on the line of the Ohio river, near Louisville or Cincinnati. At least one half of the line is fit for tobacco culture—a crop of great value to a railway, inasmuch as it furnishes a freight that can stand heavy charges for transportation, and leads to the importation of large quantities of artificial manures. In short, the assemblage of conditions is peculiarly favorable for the development of industries in the region adjacent to the line of this proposed road.

The difficulties of a passage through this section are by no means great. In the autumn of 1875 I rode the general course a railway line will be compelled to follow, and could perceive no material obstacle. The valleys of the streams are sufficiently gradual in their slopes to admit of a passage across the drainage without very heavy grades. At about the line of the Kentucky border with Tennessee, there begins to be decided indications of the rise to the Tennessee table-

land. This extensive elevated region affords a formidable barrier to the passage of a railway from the northern line of Tennessee down to the river of that name; so that the line from Glasgow Junction to the Gap, by way of Barbourville, is about the only east and west road that is likely to be built through this part of the South for many years to come.

While this line must naturally look to the people of the district it traverses for much assistance in its construction, it should be undertaken in the interest of the great transportation interests that centre near St. Louis and about the junction of the Ohio and Mississippi rivers. The northern roads to the sea have been built in the interest of the populations which fill the country north of the 40th parallel of north latitude, and naturally serve the interests of those sections for European shipment. The waters of Chesapeake Bay—the great harbor of Norfolk especially—furnish the best outlet for the commerce of the region south of that line. Year by year it will be better and better understood that the transportation of the heavy freights of the West can be more cheaply accomplished from Norfolk than from New York, on account of the difference in the distance of land carriage. Moreover, roads can be constructed and operated in this almost snowless and nearly winterless belt far more cheaply than they can be in the latitude of New York and Pennsylvania. Add to this, the greater length of line within the region abounding in coal and iron, and we perceive the conditions which will, in time, determine a large share of the commerce of the country to lines which will traverse this section. But the roads will not build themselves; and it will be quite possible for Kentucky to remain as she is—the most inaccessible State in America, a State whereto capital and labor cannot penetrate, and out of which its wealth can find no suitable way—if its people do not determine it shall be otherwise.

Situated as we are, with a people essentially agricultural, and therefore without the large capital which comes from massed industries, with our wealth of resources without value, until we can give them the results of millions of expenditure,

the question comes as to the possible plan of development. While this is a question quite outside of geology, I venture, as one who has watched with great care the methods taken in different countries for developing such works, to say a word, by way of suggestion. Our Constitution denies the right to the General Assembly to contract debt. Some may regret this provision, though I confess I am not of their number. I believe, however, it is quite within the province of the Legislature to impose taxes, and, with the money well in hand, to undertake those improvements which the advance of the State seems to demand. It also has the right to employ its convicts in the way it may seem best. If fifty years ago the men who have owed service to the State for offenses against its laws had been put on public works and kept steadily engaged, say one half upon slack-water navigation and one half on railways, we could have had at this moment, as the result of their labor, at least six hundred miles of slack-water navigation, and every railway here designated as necessary could have been completely graded, bridged, and made ready for the rails. Companies could doubtless be found to take roads at this stage of their construction, which would, for leases of say fifty years, at nominal rates, complete the work of equipping them for travel. Within a relatively short time they would fall into the hands of the State, to be released at a considerable direct gain to its revenues, to say nothing of the gain from increase of taxable property. By leasing these works, the State would avoid the great dangers of administration, which would come from direct management by her own officials.

Fifty years, with their possibilities, are in the life of our Commonwealth, let us hope, but as a day. With the yearly increasing population and the unhappy growth in the number of prisoners sentenced to labor, the work can be done in a far shorter time, beginning now, than it could have been done beginning fifty years ago. The annual cost to the State for these improvements would be the provisioning, clothing, guarding, and directing of say six hundred convicts, the purchase of

tools, &c., all amounting to about one hundred and fifty thousand dollars per annum. Who is there who knows the life of a convict in our penitentiaries who does not believe that the moral gain of breaking up our convicts into small bands, and employing them in healthy occupations, which are of account to the future of the State, would be worth this relatively trifling sum?

But the gain to the State is manifold, and to be reckoned in something more tangible than morals. The whole central region of the State is languishing for want of a direct road to the great commercial centres of the East. If the State would take, say three hundred convicts, on to the Lexington and Big Sandy road, it would be ready for the rails within five years. There is an abundance of capital that would be glad to lease it for fifty years on condition of ironing the way, and at the end of that time returning the property to the State. The Commonwealth would then have in its possession a property which, judged by the value of other east and west roads, could be reckoned as worth at least sixty thousand dollars per mile, or about five million of dollars, besides having had the profit of the gain to its citizens, which would be sure to accrue from the building of the road. At the present rate of growth of our population, the average number of prisoners fit for service on public works, during the coming thirty years, may be safely set at one thousand five hundred. This gives a total of about thirteen million five hundred thousand days' labor that can be realized in this work of public improvements. Calling this work equal to labor at two dollars per diem—a low valuation, considering that there are skillful carpenters and masons in the work, and other men trained to their trades—we would have a total of thirty-seven million dollars in our public improvements. Allowing that our railroads amount to five hundred miles, costing for grading and bridging thirty thousand dollars per mile, and that our slack-water is extended to two thousand miles, at six thousand dollars per mile, we still fall within the limits of our estimates. Granting that no dollar of profit was ever received from this form of improvement, it

is clear that the State would be repaid many fold for the cost of the works. But when we see that every mile of these improvements connects itself with the great enriching industries, it is easy to believe that the State will, after fifty years of this system of improvements, find itself in possession of a really imperial revenue from her own commercial avenues.

How advantageous it is for a State to hold possession of its commercial channels, is well shown in the little kingdom of Belgium. In that little State, less than a third of the area of Kentucky, and with far less in the way of mineral wealth, there is a rich population of more than four million souls. A large part of the success of this State has been due to the fact that the control of the channels of trade has been kept in the hands of a well-administered government. The State owns the railways, and makes them the cheapest lines in Europe, and still gains some profit from them. It will be possible for our Commonwealth to get the same control of the east and west lines, which are destined to become the great trade lines from the Mississippi Valley to the sea.

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GEOLOGICAL SURVEY OF KENTUCKY.

N. S. SHALER, DIRECTOR.

DESCRIPTION

OF THE

PRELIMINARY TOPOGRAPHICAL AND GEOLOGICAL

MAPS OF KENTUCKY,

EDITION OF 1877,

BY N. S. SHALER.

PART VI. VOL. III. SECOND SERIES.

347 & 348

DESCRIPTION OF THE PRELIMINARY TOPOGRAPHICAL MAP OF KENTUCKY, EDITION OF 1877.

INTRODUCTION.

This map is designed especially as a record map for the use of the Kentucky Geological Survey, and in order to fit it for that use contains some peculiarities which require explanation. It will be noticed that the names of towns are, in some cases, limited to the county town and other important towns of each county. This has been done in order to leave more space for the notes of the officers of the Survey. Subsequent editions of this map will give more of these local names. Special efforts have been made to secure the names and direction of flow of all the streams. Their relative size is also given, with an approximation to accuracy, by the width of the lines which designate them. The several river systems are distinguished from each other by the shading of the surface.

It will be observed that there has been no effort made to represent the relative level of different parts of the State by indications showing the hills and mountains. The reason for this is, that, except in about five thousand square miles of the surface where the special topographical work of the Survey has been completed, no data exist for making such a map. In this, as in all other topographical work, the Geological Survey is at a very great disadvantage, compared with similar undertakings in other States. Kentucky never received a survey after the plan of the other States whose public lands belonged to the General Government, but has remained to this day without any other basis for a map than has been furnished by various surveys made for railways and other public improvements, together with the various military

surveys made during the late civil war. These were combined during the later years of the war by the orders of the generals commanding in succession this department, and from this military map of Kentucky and Tennessee the topography of the appended map has in good part been taken. The railroads are laid down from their several surveys, and the rivers are from the surveys that have been made at sundry times. It is intended that this map shall be supplemented by successive editions, giving the connections and improvements which may be made from year to year, during the time required to accumulate the materials necessary to form a larger and better map of the State.

It will be seen that the map is made on the projection known as the projection on the cone, the meridians being drawn parallel to each other. This arrangement, though objectionable on some accounts, is the most convenient for all purposes: the distortion it brings about is not worthy of notice in an approximative map such as this. It is the projection adopted in the military map which has furnished the general plan of this. The indication of the meridians are not to be taken as definite, or by any means certain for their positions. They are doubtless nearly true where they cross the Tennessee line; and the base lines furnished by the old Survey serve to help the adjustments; but, on the whole, they are only rude approximations. In order to facilitate reference to the map, it will be seen that the spaces of fifteen inches each have been numbered for the meridians and lettered for the parallels. This will make the designation of any particular spot a matter of comparative facility.

The average error of the geological position of the points given on this map is great. The triangulation work under way has proven, that for the southeastern part of the area the error of position of points in relation to each other is so great, that any two points given as one hundred miles apart on the map may be no further than ninety-seven, or as much as one hundred and three miles from each other. The error in compass course of the lines joining any two points is proportion-

ately quite as great. Successive editions of this map will progressively eliminate these errors.

PRELIMINARY DESCRIPTION OF THE TOPOGRAPHY OF KENTUCKY.

To aid in the understanding of this map, as well as to give a general idea of the features of the country that are not represented by it, I shall give a brief account of the surface features of the country, and some explanation of their connection with the underlying rocks. This will require a short statement of the geology of this district. In this statement all details not necessary to a general understanding of the subject will be carefully omitted.

The whole of the State of Kentucky lies within the valley of the Mississippi river, and about all of it within that section drained by the Ohio and its tributaries. Scarce any other State in this country has a drainage so entirely limited to one direction of flow. Every part of it, save a small strip along the Mississippi, lies on the southern tributaries of the Ohio river, the meanders of which river form nearly seven hundred miles of its northern boundary. This river, one hundred and forty miles of the Big Sandy, and about fifty miles of the Mississippi, below its confluence with the Ohio, constitute the river boundary of the State, and form the whole of its west, northwest, north, and northeast lines. The southeast face is formed by Cumberland Mountain and some of its associated ridges, and the south face by an arbitrary east and west line, extending from Cumberland Gap to the Mississippi river, with a few irregularities in its course. Thus the forty thousand square miles of area is inclosed in an irregular pentagon, four sides of which are natural boundaries of river or mountain range, and only the fifth is a conventional boundary. The topography of the State is as simple as its outline. The Ohio river, so prominent a feature in its map, is the key to most of its surface. All except about one eighth of its area, situated in the southeast corner of the State, lying within a line extending from the north end of Floyd county to the southwest side of Whitley county, may be regarded as a part of the

valley table-lands of the Ohio, varying in character according to their underlying rock, but owing their form almost entirely to the cutting action of the rivers, acting upon rock which has never been thrown into great mountain folds. In the formation of this surface there have been, with slight exceptions, no other factors than the hardness of the rocks and the energy of the wearing agents—running water and frost. This has given a surface in general rather level, but elevated high above the plane of the main streams, which cut for themselves deep valleys with precipitous sides, often true cañons in their form. The height of these elevated plains above the sea, and above the drainage, varies a good deal, according to their position in the State and the nature of the rock in which they have been excavated. At Hickman, the base of the topography may be placed at about two hundred and fifty feet above the sea, rising from twenty feet in the lowlands to one hundred feet in the small area of Tertiary deposits in the Chickasaw plateau. From this section, towards the eastward, there is a continual increase of height. This may best be represented by drawing radiating lines from the mountain area of Southeastern Kentucky in every direction to the Ohio, this mountain section being the stream centre of the South Ohio area, all its southern tributaries pointing towards that region. The drainage levels rise with great uniformity in that direction; the only great differences of level being caused by the change in the height of the plateau between the streams. Whenever these lines cross the line of outcrop of the different formations, there is apt to be a sudden change in the character of the surface, and often a distinct cliff-like ridge occurs. Muldraugh's Hill and Big Hill are good examples of this structure. Many of these lines of escarpment or outcrop are commonly represented as mountains on the several maps which have been published. They differ from ordinary hills, inasmuch as they are sloped on only one side; their face may be cut so as to make many steep valleys and isolated hills; but as a whole the outlines are only accidents connected with the wasting of the escarpment. They also differ from the ordinary hills in

being steep-faced on one side only, while ordinary mountain ridges are steep-faced on their several sides. These escarpments, again, differ from mountains of elevation in having the rocks that compose them lying in essentially horizontal positions, while in the mountains the disturbance to which the rocks have been subjected have done much to give them their form and elevation.

The surface of the greater part of Kentucky having been in the main the product of erosion, quite without the complication given by the various abrupt tiltings occurring in the mountainous regions of the globe, it is naturally found to lie in these comparatively level table-lands, which always mark horizontal strata. The data does not yet exist for determining the height of every part of the State; but, from the before-described base at the northwest corner, we rise to about five hundred feet for the table-land of the Carboniferous of Western Kentucky, between the Cumberland river and the Louisville and Nashville road. Going still further east, the gain in height is continued to a line drawn from Lexington southwesterly to the Kentucky boundary, where the surface attains to a height of about one thousand feet above tide-water; but the table-land rises more rapidly than the stream-beds, so that the valleys of the stream-courses are deeper as we go towards this central region. Passing this line, extending south from Lexington, we come into a region where, except near the Ohio, the rise in the stream-beds continues, while the table-lands rather lose in height. The cause of this is found in an important though comparatively slight change in the position of the rocks beneath this line, extending from Lexington towards Nashville. This line extends along the top of a low ridge, formed at a very early date by a broad folding of the rocks of the earth's crust. This ridge seems to have been more than four hundred miles long, about a hundred miles in its east and west transverse measurement, and rising to a height of from three to eight hundred feet. At Cincinnati and at Nashville this ridge had its greatest height. In the country through which the Green river passes lies the lowest part of the ridge.

The ridge extends some hundred miles or more to the north and south of the highest points at Cincinnati and Nashville. In general character it closely resembles the other mountain ridges of the Allegheny system: its course is the same, and the greater elevation of the ridge near either extremity is also a character in which it resembles the mountains on the east.*

This Cincinnati-Nashville axis causes the central part of the State to rise above the level it would otherwise occupy. East, south, and west of the Lexington summit is a semi-circular trough, extending from the Ohio river, in Mason and Lewis counties, around the outcrop of the soft beds of the Devonian shale, which lie just over the Cincinnati Group, through the counties of Lewis, Fleming, Bath, Montgomery, Estill, Madison, Lincoln, Marion, Nelson, Bullitt, and Jefferson, to West Point, on the Ohio river. This depression is due to the wearing out of the soft beds of the Devonian shale, and, in a less degree, to the erosion of the soft beds which lie at the top of the underlying Silurian beds, and the base of the overlying Waverly shale. The depression of this valley is very slight, provided we reckon from the top of the highest hills to the bottom of the lowest valleys. The hill-tops are almost as high as those of the Silurian district, and the river valleys fall, on the average, but little below the level of those which lie over the broad Nashville-Cincinnati mountain; but the hills in this section are apt to be mere knobs, capped by a plate of the hard beds of the superior rocks which have worn away. The valleys are relatively very broad. It often happens that a small rivulet that can not be ranked more than a sixth-rate stream—one too small to require bridging on ordinary roads—comes to have a broader valley than a stream like the Kentucky river, where it cuts through hard rock.

In general we may say that the table-land district of Kentucky, which includes all its area except the small mountain district before described, has its hill-tops about conformable

* For a fuller account of this ridge, see notes on the question developed in the explorations of the Geological Survey, in this volume.

to an inclined plane sloping from the Ohio and Mississippi upward towards Cumberland Gap, and only varies from this uniformity of structure in the width and depth of its valleys.

The distribution of the main rivers of Kentucky, though simple and conformable to the general slopes of the country, has some points of special interest which deserve mention. It will be noticed that they all head in or near the mountain mass in the southeast corner of the State, and pass on more or less distinctly radiating lines towards the Ohio river, falling into it at right-angles to its direction of flow. Extending our view beyond the limits of the State, so as to take in the whole system of tributaries of the Ohio, we then see that the main drainage centre of that basin is found in the great system of mountains and valleys belonging to the Appalachian chain, within the boundaries of Eastern Tennessee and Virginia. The Tennessee and the Cumberland originate well within those mountain walls, and, limited by their barriers, flow to the southwest, but, guided by the general slope of the rocks, always pressing against their walls on the west, and taking advantage of every weak place in the line to gain something on their western journey. In this westward advance they are aided by two elements in the structure of these mountains: First, the frequent transverse breaks in the rocks of the mountains caused by faults. Second, the successive lowering in the height of the valleys as we go to the westward. Generally a good part of these mountain ridges consist of limestones which caverns easily, and so readily begins a break from one level to another. As the Tennessee begins far within the central valleys of the Alleghenies, it has a long wrestle with the mountains as it follows their general slope southward, and their cross-slope to the westward, until it has quite crossed the mountain. It then turns at once to follow the general trend of the valley of the Ohio. The upper Cumberland makes but one break across a mountain—that at the gorge where it passes Pine Mountain. It then has to encounter the Cincinnati-Nashville axis, which causes it to keep away

from its normal course until it passes that ridge, when it turns towards the Ohio and becomes parallel to the Tennessee.

The Green river does not get far enough east to feel any influence from the Cumberland Mountains, and so follows the normal course of the valley tributaries of the Ohio. The same may be said of Salt river and of the Kentucky, save at its very head. A few of the upper tributaries of the last-named river lie within the disturbed region of the Cumberland Mountains. As shown on the map, the courses of these mountain-bordered tributaries depart sharply from the trends of the other branches. These tributaries of the Kentucky, which fall within the mountain lines, are all quite small, none of them exceeding twenty miles in length. The Licking river, which occupies only a limited area between the Kentucky and the Little Sandy and the Chatterawha or Big Sandy, does not attain to the disturbed belt of the mountains, and the other smaller streams between the Licking and the eastern border of the State are also limited to the table-land region. The Chatterawha or Big Sandy river differs in some important regards from the other Kentucky rivers, and from most of the main tributaries of the Ohio, especially in the peculiar feature of having one branching, where the stream is divided into two equal forks. This unusual arrangement is not readily explained, from our present inadequate information as to the structure of the rocks in that region. Only the westernmost of these branches has its head waters within Kentucky. The uppermost tributaries of this branch turn abruptly into the trends of the Cumberland Mountains, flowing to the northeast until they escape from the mountain troughs.

We have now considered the relation of the Kentucky rivers, and seen that, while their head waters are to a certain extent involved within the mountain valleys of the Appalachian system, these streams as a whole, at least within her borders, are quite purely table-land rivers, and conform to the same laws as those tributaries which flow into the Ohio from the north. We may now pass to the details of their structure.

There are some peculiarities of the Kentucky streams which, though not evident on the map, are quite important, both in an economic as well as in a scientific way. The most important point is the rate of fall observable in the course of the streams. The average fall of the Ohio, Tennessee, and Cumberland, within the limits of Kentucky, is probably less than six inches to the mile. The strictly Kentucky rivers have much greater rate of descent, on account of their relatively shorter courses. The Big Sandy river, for instance, falls half as much in its short course as the Tennessee in its course of thrice as many miles. The average fall of the Kentucky, Licking, and Sandy rivers is about one foot to the mile; but this is distributed in a very unequal way—the fall ranging from an average of three feet on the upper half to six inches or less on the lower half. The northern tributaries of the Ohio have about double the rate of fall of its southern affluents. This less rapid inclination in the southern tributaries of the Ohio is a curious feature, and one not readily explained, save in a general way. It is, in good part at least, due to the fact that the drainage slope on the south is far wider than on the north; so that, while the rivers have a greater height for their descent, they have also a much greater proportionate distance in which to accomplish their journey from their source to the main stream. Besides this, they come from a region having a much greater rainfall than those on the north of the Ohio, and thus, being larger streams, have in time cut their beds deeper into the rock foundations.

These features give to our Kentucky rivers a great economic value—a value not possessed by any of the northern tributaries of the Ohio, and by none other of its southern streams, except the Kanawha and Monongahela rivers, which have the same features. Of all the tributaries of the Mississippi, these rivers which pass through Kentucky are the most susceptible of improvement, and, when rendered navigable, the most likely to be the means of developing important industries. Their channels are well defended by rocky banks, which afford excellent foundations for dams, and their head waters are

admirably suited for the storage of water to insure a constant navigation. When they have received that improvement of which they are so susceptible, they will afford at least two thousand miles of slack-water navigation, of which more than one half will be through the richest field of coal, iron, and timber that is afforded by any part of this country. They are the natural avenues to a vast store of the most important bases of industry.

Before leaving the consideration of our rivers, it is well to notice the way in which the evenness of their distribution shows the uniformity of the geological structure of Kentucky. They, one and all, originate in the beds which belong in the Carboniferous series of rocks. With the exception of Green river, all of them have their sources in the rocks containing the coal beds. This river has its head waters in the Sub-carboniferous limestone; but, as if to make amends for the loss the river has received from the wearing away of the coal beds through which its head waters once flowed, its course is so laid as to pass through the important coal basin of the western half of the State, where, for a hundred miles or more, it is bordered by an admirable coal field.

Close consideration of the map will show that there are considerable areas in the district it represents where there is a curious absence of streams: one of these, and the largest, lies within the limits of the counties of Warren, Edmonson, Barren, and Hart. In one direction the traveler may pass for about fifty miles without encountering a single surface stream. The whole drainage of the country is underground, through the vast and interminable system of caverns which honeycomb the whole area. The water falling on the surface courses for a few hundred feet, and then plunges downward through a sink-hole into the subterranean ways below. On the surface we have either a plain pitted all over by these sink-hole entrances into the caverns below, or else a system of ridges and valleys which have survived the loss of the streams that once flowed through them, and their water-courses are now replaced by rows of sink-holes, which swallow the streams

before they become more than trifling rills. For each of the extinguished surface streams which, as the sandstones of the coal period in which they once flowed were cut away, disappeared in limestones below, there is an answering cavern line, or rather a set of caverns, tier on tier, which mark the successive down-working of the stream in the different levels of the mountain limestone. There are several other regions in the State where there are very extensive caverns, but none so important as this. Generally the lesser streams alone have their courses subterranean, while the considerable creeks flow in the open air, occasionally sinking for a certain distance. Breckinridge and a part of the adjoining counties have this character, and near all the outcrops of the Sub-carboniferous limestone it is generally found; so that the caverned area of the State, or the region where the streams generally work for much of their course underground, probably exceeds five thousand square miles, or about one eighth of the whole surface of the State. In some sections, as in the cavern district of Carter county, the caves have been deeply worn down, so that they have had their roofs much stripped away, leaving fragments of the arches in the shape of natural bridges, which here, as elsewhere, are always but the ruins of cavern vaults.

The rivers of Kentucky, with few exceptions, and those mainly in the mountain regions, occupy deep sunken valleys with very steep walls. Within and below these walls we have marks of the recent action of the rivers at various points above their present plane. Above their level the surface gives us evidence that the rocks have been decaying in their places for a very great time. Yet, upon these upper levels, at a height of one, two, or even three hundred feet, we sometimes find river gravels, showing that the streams have worked for great lengths of time in their present neighborhood; and showing further, that, in the vast time that has elapsed since the rivers flowed on these ancient beds, there have been no agents at work which could efface their work. This, in itself,

is evidence enough that the surface of Kentucky was not swept by glaciers during the last geological period.

The accompanying map of the river basins of Kentucky will show the irregular way in which the surface of the State is shared among the rivers. It is not easy to account for this irregularity in the disposition of the streams away from the mountain regions. Away from those disturbed regions there are only slight irregularities in the rocks, which do not seem to have any power of determining the range of a river basin. Other explanations being wanting, it seems worth while to suggest that the topography we have here may be inherited from the conditions given by the beds in which it was formed. Each generation of rivers is like a generation of living beings. Its character depends not only on its own existing conditions, but on the condition of those that have gone before. When our streams were running on levels that are now hundreds, or may be thousands, of feet above their present level, the rocks they were cutting may have been disposed so as to give them their present arrangement, and their present order may have been inherited with little change.

At certain points these local peculiarities of distribution of streams are so great as to baffle conjecture. The drainage opposite the mouth of the Sciota, in Lewis and Greenup counties, is a case in point. This drainage area is all sloped away from the river for a considerable stretch along its banks, the hills, six hundred feet high, shedding their water to streams that only find their way to the main river after very devious courses. Another puzzling case is that of the drainage on the south side of the Kentucky river from Frankfort to Dick's river. The head waters of Salt river take nearly all the water of the region bordering the Kentucky on this part of its course. A glance at the map will show that for nearly thirty miles the head waters of Salt river run parallel with the Kentucky, and at an average of less than ten miles from that stream. It is not improbable that the fault system which crosses the Cincinnati axis at this point is in some way connected with this peculiar system of drainage, though I have

not yet been able to determine this point in a satisfactory manner. It seems likely that the rivers have flowed for a long time in the same general position where we now find them. This is proved, not only by the ancient gravels at a great height above the present high-water levels, but by such case of clearly parallel channels as those of the Cumberland and the Tennessee rivers. These run near each other for over seventy miles of their course, the average distance apart in this part of their course not exceeding ten miles, and being for about a score of miles reduced to half that distance. If either of these rivers had wandered greatly since they became parallel to each other, the result would necessarily be their union in one stream.

The same limitations may be put to the wandering of the upper Cumberland where it flows through Knox county. As will be seen from the notes on the surveys made at the time, it was proposed to direct the waters of the upper Cumberland into Goose creek and thence into the Kentucky, the valley of Goose creek lies considerably lower than the valley of the upper Cumberland; so that the natural passage of the Cumberland would have been directly to the ~~south~~north west after it passes through Pine Mountain and into the upper Kentucky. If the Cumberland had ever swung to the north as much as fifteen miles, since the establishment of the relative height in their valleys, then it would necessarily have been diverted from its present course into the channel of the Kentucky. As this difference in height in the Cumberland and Kentucky river valleys is due to the greater thickness of the Conglomerate in this section, it dates back to a very early time. I am disposed to believe that the relative levels of these valleys have been about what they are now for a very long time; so the probability is that the Cumberland has never wandered far enough to break into the slope of the Kentucky.

Although not one half the actual sinuosities of our rivers are indicated in this preliminary map, it will be seen that their course is exceedingly tortuous; far more so than the course of

the average American streams. Their comparatively gradual descent is accounted for by this winding character. It is not so easy to account for the windings themselves. It is likely that this is the normal character of streams whose valleys have never felt the tread of the glacial rivers, which necessarily tend to take out the windings of the river in a very summary fashion. Throughout New England and all other extensively glaciated regions known to me, the general character of the valleys is just what it is in those parts of the Ohio river system, lying north of the Ohio, which have been subjected to glacial action. An ice stream working in the Kentucky or Licking valleys would have made a broad U-shaped valley, instead of the narrow V or cañon-shaped gorge. This existing structure of our Kentucky valleys is a strong proof that, since they began to occupy their present beds—that is to say, for the last four hundred feet of their cutting—there has been no ice action in their valleys.

The tortuous character of our Kentucky rivers gives the State more river front than occurs on any other region where I have had the opportunity of making measurements. As there is usually only about four hundred feet of fall to be accomplished from the smallest tributaries to the main Ohio, it is readily seen that the head waters of the larger streams have a very gradual fall. It also follows that the average rule of fall of any stream is generally proportionate to the distance it has to flow to find the Ohio. Many of the small tributaries which fall into the Ohio, after a course of twenty miles or less, fall more than half the distance that the Kentucky river does from its uppermost head waters to its mouth, though the actual distance traversed in all its windings is not less than four hundred miles. As the amount of descent in the case of the Kentucky river cannot be more than twice that of the shorter stream, it is evident that its average fall is not over one tenth that of the shorter stream. I believe it will be found that the same length, measured on the head waters of the Kentucky or other principal rivers, and on the small tributaries of the Ohio, say those less than a score of miles in

length, will show a less rate of fall than on the shorter stream. Although there is no evidence in the way of measurement to show this fact, it may be inferred from the consideration that, though the Kentucky at the Three Forks is over five hundred feet higher than the Ohio at its mouth, the tributaries for a great distance above that point fall at the gradual rate of less than one and a half feet per mile. The length of the confluents of the stream seems to increase, on the whole,as we ascend the river, though the general level of the uppermost waters does not rise. This compels us to the opinion that the upper branches must fall less than the lower. This gives these rivers the essential features that fit them to be used for canals, and fits them for the passage out to the main river of the great stores of coal and iron which are found about their head waters.

The fact that the lowest points in Kentucky are about two hundred and fifty feet above the sea, and that nine tenths of its surface is at least two hundred feet above its nearest river, makes it on the whole free from swamp land. Except along some of the smaller rivers and creeks, where accidental obstructions have clogged the passage of the streams, the actual permanent swamp land is limited to the region west of the Cumberland river. This extreme westerly section will probably average fifty feet above the level of the extreme high water, and at least two thirds of its surface will, when the natural drainage is improved by clearing out the streams, be found to have sufficient surface drainage. About one thousand square miles of the surface west of the Tennessee, lying below the river bluffs, and representing regions recently abandoned by the streams, is subject to continued flooding to such an extent as to make cultivation hazardous or impossible.

These lowlands are probably due to the wandering action of the rivers, but may be, in part, owing to the subsidence of this region, or rather the elevation of the region to the southward by a few feet. The problem of the drainage of this low area has been elsewhere considered; but the actual value of the drainage problem to the State at large is relatively small.

The swamp section is not over the fortieth part of its surface. Small though it is in area, this belt of low-lying land is the richest in the State, and the floods, which damage it in their uncontrolled form, would, if their visitation could be limited to the winter, be of immense advantage from the continued fertility they bring in their train.

A large part of this occasional flooding has been brought about by the reckless mismanagement of our rivers, and may be overcome in the progress of improvement of their conditions.

GEOLOGICAL SURVEY OF KENTUCKY.

N S. SHALER, DIRECTOR.

ANNUAL REPORT

OF

N. S. SHALER, STATE GEOLOGIST,

FOR THE YEAR 1877.

PART VII. VOL. III. SECOND SERIES.

STEREOTYPED FOR THE SURVEY BY MAJOR, JOHNSTON & BARRETT, YEOMAN PRESS, FRANKFORT, KY.

ANNUAL REPORT OF N. S. SHALER, STATE GEOLOGIST, FOR THE YEAR 1877.

The operations of the Survey during the field season of 1877 have been less extensive than during the two preceding years. This was owing to the carefully determined plan of extending the field work, during the year 1876, beyond the limits of the half of the biennial appropriations especially belonging to that year. In this way a larger part of the work done by the Survey, under the last appropriations, will be ready for publication before the session of the Legislature in 1878. At best, a large part of the labors of any survey, working in a rich field, must be long incomplete, owing to the need of awaiting the progress of the search for fuller information on many of the questions it encounters. It is generally impossible to bring the results of any one summer's field work into shape for publication before the coming spring. This plan of putting the burden of the work upon the first of the two years gives time for the completion of a larger share of the work undertaken in the intervals of legislative action, and enables the officers of the Survey to keep the work in better shape for legislative criticism.

The largest part of the work done during the preceding year has been given to the extension of the topographical surveys. The following summary will make the operations on this branch of the work sufficiently clear.

In the eastern district, Mr. C. Schenck has carried forward his map work in Menifee and adjoining counties, substantially completing the map of the district between the Licking and the Kentucky rivers, and extending for a depth of about forty miles east from Slate creek. This work, together with the reconnoissance of Mr. Crandall, gives us a tolerably complete basis for the topography of the district between

the head waters of the Licking and the Kentucky. In the central district Mr. Schenk has carried forward the topography in Cumberland and Clinton counties, completing the work over a district containing about five hundred square miles. I regret that the exhaustion of the appropriations made it necessary to end the work in these counties before its completion. Another season's labor would make it possible to finish the detailed topography of this important oil district. The district between the Cincinnati Southern Railway and the Louisville and Nashville Road has been so much traversed by carefully-made railway surveys, that it will be possible to complete the topographical work there with a relatively small amount of labor. On account of its rich resources in coal oil, coal, and timber, as well as its excellent agricultural character, it is important that it should be among the first to have an accurate representation of its surface.

The larger part of the topographical work done during the present year has been given to the district west of the Louisville and Nashville Railway. The map of the eastern border of the western coal field has been completed to the Ohio river. This part of the district, embracing nearly two thousand miles of area, and extending from near the junction of Big Barren and Green rivers to the Ohio at Hawesville, is now accurately mapped on the scale of six inches to the mile, with a careful study of the heights along the streams and roads. The published map is reduced to the scale of one inch to the mile. One half of it is given in the first volume; the rest will appear in the fourth.

The task of determining the outline of the western face of this western coal field was taken up in the month of June. The three parties, in charge of Mr. W. B. Page, began this work, in the district between the Tradewater and the Cumberland rivers, in the month of June. This work was pressed with great energy by the officer in charge, and with such success, that when the exhaustion of the appropriation forced its discontinuance, the data were all in hand for the making of a complete outline map of this district. Three weeks more

work, with the same force, will serve to complete the field work for a map of the whole district bounded by the Ohio, the Cumberland, and the Tradewater rivers, south to the Elizabethtown and Paducah Railroad. This map work will be reduced and drawn during the autumn, and it is expected that it will be ready for publication by the first of February, 1878. Besides its importance as an advance in determining the outline of the western coal field, this map will have a very great value in aiding the development of this rich territory, which abounds in the elements of agricultural and mining prosperity. The natural outlet of the larger part of this district, as I have elsewhere repeatedly remarked, is by the channel of the Tradewater river, a stream that remains unnavigable, owing to the want of comparatively inexpensive improvements. The completion of this topographical survey cannot fail to have a very important influence in calling attention to the importance of canalizing this stream.

The last work of importance done by the Topographical Assistant was to get the existing data for a map of the "Purchase" district, or the counties west of the Tennessee, into shape for publication. This district, having been incorporated into the Commonwealth long after its foundation as a State, was provided with a township survey, which seems to have been made with reasonable care. The notes of these surveys have never been reduced into a shape for publication. They have now been copied and reduced by Mr. Page and his aid, Mr. Hoeing, and will be platted during the coming winter. They will then be revised in the field, in order to bring the work to date, and then published on the scale of one inch to the mile. At the same time a competent officer will make a study of the levels on the district, with the view of furthering the consideration of its important problems of diking and drainage. In the reports for the preceding years I have frequently referred to plans for the bettering of the drainage, and the prevention of floods in this district. I have become convinced, however, that the first step must be to prepare a

sufficient map of the district on which, as a basis, a study of the measures of betterment may be founded.

The summer's work has, despite its brevity, given us a larger area of topography than any other campaign of the Survey. About three thousand square miles of area were brought into shape for platting, and if we include the "Purchase" district in our computation, we may claim that not less than one sixth of the whole area of the State has been brought into shape for mapping during the present year.

As time advances, and the officers of the Survey become the better trained for their work, it is possible to attain a higher and higher degree of skill in this difficult task of making good, and at the same time inexpensive, maps. During the first two years of the Survey work, the map work done cost not far from five dollars per square mile for the field work alone, and about one third that sum for the platting, reduction, and engraving of the results. This season the experience and the increased skill of the topographer have enabled us to bring the cost of the field work down to less than three dollars per square mile, and I hope to accomplish a nearly proportional reduction in the cost of putting the map into the engraved plate. I am satisfied that it will be possible henceforth to proceed with the work of making a careful topography of our State in a very economical way. I believe that a map with all the principal roads and streams—say all county roads and all streams with beds over three feet wide run by the telemeter, and the lesser streams and unimportant roads either paced or run by the odometer, can be prepared at a cost of not exceeding four dollars per square mile. This includes the cost of the field and office work, as well as the expense of engraving the same. A small additional expense, not exceeding one dollar per square mile, will place contour lines along the roads and creeks, so as to give an approximation to the levels in the country. The errors in map work of this kind will not be considerable enough to be traceable on the scale of one inch to the mile. The error will fall within the width of the lines used to denote the streams, roads, &c.

Although this work is not up to the level of accuracy of the great European surveys, or of the Coast Survey in this country, it will, nevertheless, be superior to that of any State on this continent. When brought within the triangulation system that is now in progress across the State, these maps will give a perfectly accurate idea of the horizontal relations of every point in the State. The determination of the contour lines for every fifty feet of altitude along the roads and streams, will give sufficient data for the vertical element of the topography, though it is to be regretted that the cost will not make it possible to connect the lines of equal height over the whole surface.

The geodetic work of the Coast Survey, which has been going on within the State for the past three summers, has done much towards the accomplishment of its purpose of aiding in the construction of the State map. The reconnoissance has already been extended from the Cumberland Mountains to Louisville, the area explored having an average width of fifty miles. The map in the first report in the fifth volume gives the condition of this work for the end of the second year of its progress. It has already afforded data for a great many corrections in the maps of the Survey. Through it we know the relative position of a hundred or more points in the region the work has traversed. The average error of position of these points on our old maps was probably as much as three miles, showing very clearly how impossible it was, without some such triangulation, to give the basis for a topography. I am very glad to say that there is now little doubt that this triangulation can be extended over the whole of the State, and that it will be so extended by the Federal Government. In addition to the geodetic work, strictly so-called, the Federal Government is beginning a system of observations for longitude determination at various points in the State. Columbus, Hickman, and Paducah have already been selected as stations, and work has begun at these points. When these extreme western stations have been accurately determined, it will be possible, by carefully chaining the distances between

them, to make an efficient triangulation of the flat wooded lands in this district, where ordinary triangulation is not possible, on account of the absence of hills or other lookout points. This work of determining the longitude of certain points by astronomical means will probably be extended to the eastern part of the State during the coming year.

With regard to the future topographical work of the Survey, I venture to recommend that a sufficient appropriation be made to keep at least two double parties in the field for five months each year. This will require the services of one officer during the whole of the winter months, when he will be occupied in the reduction of the work, and its preparation for the engraver. This assistant may be the only permanent officer of the topographical corps, the parties being recruited each year from the teachers and students in schools where engineering is taught. In this way it will be possible to do about two thousand square miles of topography each year; and the cost need not exceed six thousand dollars per annum. This estimate is based on previous experience of a sufficient kind, and may be relied on as a safe, though close estimate. At this rate it will require about ten years to complete the topography of the State, and the total cost of the work to be done by the State will be not far from sixty thousand dollars. The amount to be expended by the Federal Government, in the triangulation and astronomical work, will be quite as much, so that the State has two dollars expended within her borders for every dollar given to this work. The resulting map will be much superior to that of any State in this Union, and will compare favorably with the ordnance survey of Great Britain in its accuracy in all essential points. Such a map will immensely facilitate every step in the development of the State. In facilitating the platting of land surveys, in helping the laying out of roads of all descriptions, in shaping the taxation system of the State, and in a thousand other ways, such a map would, each year, return the State far more than its cost. To maintain the economy essential in this scheme, it will be necessary for the Commonwealth to make

the appropriations in such a way that there shall be a reasonable certainty of the continuance of the work through the specified term. In no other way will it be possible to retain the cost within these narrow limits.

During the progress of the present Survey, it has become very evident that a good deal will be gained by placing meridian stones in each county seat within the Commonwealth. The need of this form of aid to the land surveyors of the county has been recognized and acted upon by other States. Ohio long since completed this work, and has had the profit therefrom. The advantages to be derived from these meridian stones will be apparent on consideration of the fact that the land surveys of the Commonwealth have always been made by the magnetic compass, and that, apart from the errors of the instrument, this compass does not give the same direction in any two succeeding years. The lines of a survey made this year will not coincide with the most careful survey made twenty or fifty years hence on the same calls, because the instruments will give different directions for the required courses. If, however, there is at each county town a well-determined meridian mark, it will be possible for each surveyor to determine, from time to time, the variation of his instrument from the true north, and enter it with the notes of his surveys in the records. The Geological Survey has already established these stones in six different county towns. At these points they have been constantly used, and are greatly appreciated by the surveyors as a correction of a very dangerous source of error.

It has been found, however, that the work of fixing these meridian marks is a task of considerable difficulty, and tends to retard the regular work of our topographical parties. There is only a certain limited time in each month when the position of the pole star is such as to make it suitable for the determinations which have to be made. The topographer is generally remote from the point where the work has to be done, and loses time in his journey to the point of observation. Moreover, this work, being astronomical in its nature, demands for

its most exact results peculiar instruments and a special training. It seems to me advisable, therefore, that this work should be put in the hands of a specially designated officer, who might, if it were deemed desirable, be under the control of the Director of the Survey. I have made a careful computation of the cost of this work, and find that, including the salary of the person in charge of the work and one aid, as well as all charges for transportation, for the cutting of the stones designed as meridian marks, the whole cost need not exceed three thousand dollars per annum. I estimate that an average of thirty-five stations could be established each year, making the total time required not exceeding three years and a half. As this work is not necessary to the Survey of the State, though of the highest public utility, I shall not provide for it in the estimates, but will leave it to the separate judgment of the Legislature.

I have now to set forth the work of the geological division of the Survey during the past year. Of this much less was done than it was desirable to accomplish. The appropriations asked from the Legislature were reduced in the committee by the amount of six thousand dollars; unforeseen expenses in connection with the State Cabinet made a reduction of another thousand dollars in the means I hoped to have been able to expend, and the Centennial expenses somewhat exceeded my reckoning. As the letter of the law required me to give more care to the continuance of the topographical work and the work of stereotyping than to any other part of my task, I felt it necessary to reduce the amount of that part of the operations of the Survey which was strictly geological.

Assistants Crandall and Moore have received indefinite leave of absence, and have done no work since their preparation of the results of the last season's campaign was completed. Assistant Norwood continued employed until the data necessary for his report on Ohio county was all in hand, and until he had the data for a preliminary report on Adair county, closing his field work in July. Mr. Hermann Herzer, Palæontological Assistant, was partly employed in field work in the Upper

Cumberland, the Green River district, and near Louisville, up to September first; his principal task, however, was the arrangement of the Cabinet in Frankfort—a work that is already far advanced. Assistant Procter has been employed for a part of the year in the geology of the Upper Green River district, and in the study of the region adjacent to the line of the Louisville and Nashville Railway. This latter work is well nigh done, and will be a valuable contribution to the geology of the transportation routes within the State. This study has developed the existence of a number of valuable building stones along this line, which have not yet been brought into use. It has also served to lay the foundation of a more careful and well-directed search for oil, salt, and marl-bearing strata within this district.

Mr. L. H. DeFriese, Assistant in charge of the studies we are making on our forest resources, has been able to give only about two months' field work during the present season; this was devoted to a study of the forests in the western part of the State, especially in the Tradewater Valley and the district west of the Tennessee river. His valuable observations will be contained in the forthcoming fifth volume of this series of Reports. I hope in coming years to continue these very important studies of our forest resources. They form a large share of the immediate resources of our Commonwealth, and in their economical administration our people have a very great interest.

Dr. Robert Peter has been steadily engaged in the chemical researches of the Survey; but, owing to the retirement of Mr. John H. Talbutt, who, with our diminished resources, could not be retained as Chemical Assistant, the work has not been able to make its usual rapid advancement. The loss of Mr. Talbutt's services is a serious disadvantage to the Survey, for his energy and skill greatly contributed to the success of its chemical work. The reports of Dr. Peter will show that, even with the limited work in his department, a good advance has been made in solving the more important chemical problems which have been encountered.

The Survey has been fortunate in securing the services of Mr. Wm. B. Caldwell, jr., a well educated metallurgist, who has had the advantages of a careful training in the European establishments best calculated to give a knowledge of the problems which concern our metallic resources. Mr. Caldwell is now engaged in a careful review of the iron ores of the State, with a view especially to the methods of treatment necessary to secure the best results in the reducing furnaces where they are used. The distinguished chemist, Dr. J. Lawrence Smith, has kindly given Mr. Caldwell the use of his extensive private laboratory, and the advantage of his valuable advice in his investigations.

The work done by myself during the year of this Report has, in the main, been limited to the preparation of the Reports and Memoirs of the Survey, and the direction of its officers. It is, perhaps, well to call attention to the fact, that, as the Director of the Surveys, I am not permanently employed by the State, but only engaged for such part of the year as may be necessary for the work. It has not been necessary for me to give much over one half of my time during the past year in the offices of the Survey, owing to its limited work in the field.

The only important field researches that I have made, have been upon the oil district of the upper part of the Green River Valley, and upon the geology of the district adjacent to the Louisville and Nashville Railway. In the course of these studies I have more or less thoroughly examined about twenty counties, arranging the detailed work that is to be done by my assistants. When, in the second section of this year's report, I come to consider the problems of our geology which have been dealt with during the present year, I shall give a fuller account of this work, none of which, however, is as yet far enough advanced for publication.

The publication work of the Survey has gone forward with rapidity, though, owing to our narrow means, but limited editions of its reports could be distributed. The following is a

summary of the publications of the Survey up to the present time:

Reports of Progress. Royal Octavo.

VOLUME I. NEW SERIES.

Part I. Report on the Timber Growth of Greenup, Carter, Boyd, and Lawrence Counties, in Eastern Kentucky. By N. S. Shaler and A. R. Crandall, Assistant.

Part II. Report of the Botany of Barren and Edmonson Counties. By John Hussey, Botanical Assistant. With an introduction by N. S. Shaler.

Part III. Report on the Iron Ores of Greenup, Boyd, and Carter Counties, the Kentucky Division of the Hanging Rock Iron Region. 8 Plates. By P. N. Moore, Assistant.

Part IV. Chemical Report of the Soils, Marls, Clays, Ores, Coals, Iron Furnace Products, Mineral Waters, &c., of Kentucky. By Robert Peter, M. D., &c., Chemist to the Kentucky Geological Survey. Assisted by John H. Talbutt, S. B., Chemical Assistant. The First Chemical Report in the New Series, and the Fifth since the beginning of the Survey.

Part V. The Iron Manufacture of the Kentucky Division of the Hanging Rock Iron Region. 1 Plate. By P. N. Moore, Assistant.

Part VI. Report on the Geology of the Region adjacent to the Louisville, Paducah and Southwestern Railroad, with a Section and 4 Plates. By Charles J. Norwood, Assistant.

Part VII. Report of a Reconnoissance in the Lead Region of Livingston, Crittenden, and Caldwell Counties, including a Sketch of their General Wealth. Map and 4 Plates. By Charles J. Norwood, Assistant.

VOLUME II. NEW SERIES.

Part I. Report on the Geology of Greenup, Carter, and Boyd Counties and a part of Lawrence. By A. R. Crandall, Assistant.

Part II. Report on the Geology of the Nolin River District, embracing portions of Grayson, Edmonson, Hart, and Butler Counties. By P. N. Moore, Assistant.

Part III. Chemical Examination of the Ashes of the Hemp and Buckwheat Plants, with Remarks on its Bearing on Hemp Culture in Kentucky. By Robert Peter, M. D., etc., Chemist of the Survey.

Part IV. Report upon the Airdrie Furnace and Property, Muhlenburg County, Kentucky. By P. N. Moore, Assistant.

Part V. Topographical Report of the Nolin River District. By William Byrd Page, Assistant.

Part VI. Report of a Reconnoissance on the Proposed Line of Railway from Livingston Station to Cumberland Gap. By C. J. Norwood, Assistant.

Part VII. A Reconnoissance Report of the Lead Region of Henry County, with some Notes on Owen and Franklin Counties. By C. J. Norwood, Assistant.

Part VIII. On the Origin of the Galena Deposits of the Upper Cambrian Rocks of Kentucky. By N. S. Shaler.

Part IX. Report on the Timbers of Grayson, Breckinridge, Ohio, and Hancock Counties. By L. H. DeFriese, Assistant.

PART X. Report on the Geology of the Proposed Line of the Elizabethtown, Lexington and Big Sandy Railroad, from Mt. Sterling to the Big Sandy river. By A. R. Crandall, Assistant.

PART XI. A General Account of the Commonwealth of Kentucky Prepared by the Geological Survey of the Commonwealth.

VOLUME III. NEW SERIES.

PART I. General Report of the Geological Survey of Kentucky. By N. S. Shaler.

PART II. History of the Operations of the Survey in 1874 and 1875. By N. S. Shaler.

PART III. Notes on the Investigations of the Kentucky Geological Survey during the years 1873, 1874, and 1875. By N. S. Shaler.

PART IV. Annual Report of N. S. Shaler for the year 1876.

PART V. The Transportation Routes of Kentucky, and their Relation to the Economic Resources of the Commonwealth. By N. S. Shaler.

PART VI. Description of the Preliminary Topographical and Geological Maps of Kentucky, edition of 1876. By N. S. Shaler.

PART VII. Annual Report of N S. Shaler, State Geologist, for the year 1877.

PART VIII. Report on the Unfinished Work of the Survey of the Commonwealth under the Direction of Dr. David Dale Owen. By N. S. Shaler.

VOLUME IV. NEW SERIES.

PART I. Chemical Report of the Soils, Coals, Ores, Iron Furnace Products, Clays, Marls, Mineral Waters, Rocks, &c., of Kentucky. By Robert Peter, M. D., etc., etc., Chemist to the Kentucky Geological Survey, assisted by John H. Talbutt, S B, Chemical Assistant. Second Chemical Report in the New Series, and the Sixth since the beginning of the Survey.

PART II. Report on the Geology of Menifee County. By A. R. Crandall, Assistant.

PART III. Report on the Iron Ores and the Iron Manufacture of the Kentucky Red River Iron Region. By P. N. Moore, Assistant.

PART IV. Report on a Geological Reconnoissance of the Region Adjacent to the Kentucky and Virginia State Line, from Cumberland Gap to the Chatterawha or Big Sandy River. By P. N. Moore, Assistant.

PART V. Report on the Iron Ores of the Vicinity of Cumberland Gap. By P. N. Moore, Assistant.

PART VI. Report on the Geology of a Section from near Campton, Wolfe County, to the Mouth of Troublesome Creek, Breathitt County. By P. N. Moore, Assistant.

PART VII. A Report of Examinations made along the Paths of the North and South Running Railways of Western Kentucky. By Charles J. Norwood, Assistant.

PART VIII. A Report of a Reconnoissance of a Part of the Breckinridge Cannel Coal District. By Charles J. Norwood, Assistant.

PART IX. Report on the Timbers of the North Cumberland—Bell and Harlan Counties. By Lafayette H. DeFriese, Assistant.

PART X. On the Geology of Hancock County. By P. N. Moore, Assistant.

PART XI. On the Geology of the Region Adjacent to the Eastern Border of the Western Coal Field, from the Louisville, Paducah and Southwestern Railway to the Ohio River. By P. N. Moore, Assistant.

PART XII. On the Geology of Portions of the Upper Cumberland River Valley, in Bell and Harlan Counties. By A. R. Crandall and P. N. Moore, Assistants.

VOLUME V. NEW SERIES.

PART I. Description of the Topography of the Area included within the Reconnoissance Triangulation of the United States Coast Survey in Kentucky during the Seasons of 1875 and 1876. By William Byrd Page, Assistant.

PART II. Topographical Report of a Part of Greenup and Lawrence Counties for the year 1874. By C. Schenk, Assistant.

PART III. On the Use of the Telemeter in Topographical Surveys By C. Schenk, Assistant.

PART IV. Report on the Timbers of the Tradewater Region—Caldwell, Lyon, Crittenden, Hopkins, Webster, and Union Counties. By Lafayette H. De Friese, Assistant.

This volume is not yet completed.

VOLUME VI. NEW SERIES—CENTENNIAL VOLUME.

PART I. Thoughts on the Agricultural, Manufactural, and Educational Interests of Kentucky, suggested by a Study of the Great International Centennial Exhibition of 1876. By Robert Peter, M. D.

PART II. Report on the History, Culture, and Manufacture of Flax and Hemp, suggested by a Study of the International Exhibition of 1876. By John R. Procter, Assistant.

PART III. On the Pottery Clays of Kentucky, and their Uses.

PART IV. On the Timber Exhibits at Philadelphia in relation to the Forest Resources of Kentucky.

VOLUME VII. NEW SERIES.

Analytical and Synoptical Index of all the Publications of the Survey to this date, including those of Dr. Owen's Survey, designed to bring the matter of the ten volumes of Reports, the three of Memoirs, and the other publications of the Survey, into a shape calculated to facilitate reference to all the variously placed sources of information. It is intended to include in this volume indices of all the results of the Survey up to the end of 1878.

PHOTOGRAPHS. QUARTO.

Giving the first hundred plates of a Photographic Survey of the Commonwealth.

VOLUME I.

Scenery and Structural Geology of the Region Adjacent to Cumberland Gap. Thirty Plates, with forty pages of Text Ready in April, 1878.

VOLUME II.

The Scenery and Structural Geology of the Central or "Blue Grass" District of Kentucky. Fifty Plates, and sixty pages of Text. Ready in April, 1878.

MEMOIRS OF THE KENTUCKY GEOLOGICAL SURVEY. QUARTO.

Designed for Reports of a non-economic nature.

VOLUME I.

PART I. On the Antiquity of the Caverns and Cavern Life of Kentucky. By N. S. Shaler.

PART II. American Bisons, Living and Extinct. By J. A. Allen.

PART III. On the Fossil Brachiopods of the Ohio Valley. By N. S. Shaler.

PART IV. On the Prehistoric Remains of Kentucky. By Lucien Carr, Assistant, and N. S. Shaler. One hundred copies were printed in 1876.

VOLUME II.

PART I. On the Prehistoric Remains of Kentucky. Part II. By Lucien Carr, Assistant, and N. S. Shaler.
PART II. On the Fossil Corals of Kentucky. Part I. By N. S. Shaler.
PART III. On the Fossil Brachiopods of the Ohio Valley. By N. S. Shaler.
PART IV. On the Cavern-dwelling Races of Kentucky. By F. W. Putnam, Assistant.
PART V. On the Stratigraphical Divisions of the Rocks found within the Commonwealth of Kentucky. By N. S. Shaler.
PART VI. On Certain Fossil Mammals from the Caverns of Kentucky. By J. A. Allen.
PART VII. On the Dynamic Geology of Kentucky. By N. S. Shaler.
PART VIII. On the Collection of Cavern Insects. By Elzear Abville de Perin, of Marseilles.
PART IX. On the Living Reptilia and Batrachia of Kentucky. By S. A. Garman.

Of the Second Volume, all the Memoirs are in preparation; but probably only the I, II, VI, VIII, and IX Parts will be ready for issue during 1878.

LESSER MEMOIRS. OCTAVO.

It is designed to issue one or more volumes of scientific papers, which, from their nature, do not demand plates of the larger form. Of these, the First Volume is in preparation; for it the following Parts have been prepared:

PART I. On the Cavern Insects and Arachnidæ of the Kentucky Caverns. By A. S. Packard, jr.
PART II. On the Distribution of the Ancient Coral Reefs of Kentucky. By N. S. Shaler.
PART III. On the Former Connection of the Eastern and Western Coal Fields of Kentucky. By N. S. Shaler.
PART IV. On the Geological and Geographical Limits of the Barrens of Kentucky. By J. R. Procter, Assistant.
PART V. On the Earthquakes of 1811. By N. S. Shaler.

BULLETIN OF THE SURVEY. OCTAVO.

With the month of January, 1878, the Survey begins the publication of a series of occasional notes on various matters of economic and scientific importance, to which it may seem desirable to call attention, but which are not in shape to find their way into more complete Reports or Memoirs. It is hoped that it may be possible to issue numbers of this series quarterly, or oftener.

All these several publications are, according to law, stereotyped or electrotyped, and the plates are retained by the Survey, so that it will always be possible to issue new editions as they may be required.

The following reports have been for some time in the course of preparation, but must await the further extension of the Survey work for the necessary data for their satisfactory completion. It is designed to print the first five of these in the fifth volume of the Reports of Progress. The seventh and

the eighth are to find a place, if possible, in the sixth volume. The others will have to come in later numbers of the series.

1. On the Geology of the District Adjacent to the Louisville and Nashville Railway.
2. On the Geology of the District Adjacent to the Cincinnati Southern Railway.
3. Geology of Jefferson County. With Map. By H. Herzer, Assistant.
4. Geology of Menifee County. By A. R. Crandall, Assistant.
5. Geology of Ohio County. By C. J. Norwood, Assistant.
6. Geology of Hancock County. By P. N. Moore, Assistant.
7. On the Washing and Coking of Coals for Furnace Use. By P. N. Moore, Assistant.
8. On the Various Building and other Economic Stones of Kentucky. By N. S. Shaler.
9. On the Agricultural Marls of Kentucky.
10. On the Oil and Gas-bearing Rocks of Kentucky. By N. S. Shaler.
11. On the Salt-bearing Rocks of Kentucky.

The foundations have been laid for special reports on twenty-five counties other than those above mentioned. Each of these county reports will contain a map, geologically colored, of the county, on the scale of one inch to the mile, and a careful assembling of all that is known concerning its resources, with reference to the sources whence further information can be obtained.

As this Report is especially designed to bring before the Legislature of the Commonwealth the condition of the Kentucky Survey, I shall now briefly set forth the needs of the Survey, and its plans for future work.

In the estimates laid before the representatives of the Commonwealth in January, 1876, I applied for the sum of twenty-five thousand dollars per annum, and promised that, if this sum were given, the work should be pushed at such speed that in the present year the whole detailed reconnoissance should have been finished, the lines of transportation reported on in all desirable detail, leaving only the completion of the State map and the county reports for the future. This estimate was made with all possible regard to economy, and not in the least with a view to such a reduction as was voted in the committee. The result has been that many things have been left incomplete which would have been finished under the original estimate.

To complete the work of the Survey necessary to set forth and make available the resources of the Commonwealth, by

all the means known to our sciences, will require the continuation of the Survey for several years to come. My approximate estimates are as follows:

For the field expenses and salaries of three topographical parties, for four months' field work each year	$3,000
For the salaries of the Director, the Geological and Topographical Assistants, and the Assistant in charge of the Cabinet	5,000
For the salary of the Topographer employed in reducing the field work	500
For the chemical work of the Survey	1,000
For the field expenses of the geological parties	1,200
For stereotyping the Reports, &c., of the Survey	2,500
For the salary of an Engraver	1,000
For the purchase and repair of instruments	500
For the purchase of engraving stones, &c.	800
Office expenses, cases, postage, &c.	1,000
	$17,500

On this basis it will be possible to complete about two thousand five hundred square miles of topography each year—thus requiring about eight years to complete the map of the State. The general reconnoissance work would be finished within three years to come, when the annual expenditure could be reduced to about fourteen thousand dollars per annum. On this basis the work in ten or twelve counties could be completed each year at least, after the ending of the reconnoissance work should leave the geologists of the Survey free to give their whole labor to the completion of the county maps and reports.

This computation is based upon the most rigid economy, and the sums cannot be lessened without materially reducing the effectiveness of the work. It will also be necessary that the Director shall be able to foresee, each year, just the sum available for the prosecution of the work, in order to make his contracts with that element of permanence which is necessary to secure the best class of labor. Should it seem to the Legislature of the State not desirable to have the Survey continued to its definite completion, I would strongly urge that at least twenty thousand dollars be appropriated in order to finish the work now in hand and far advanced towards publication.

In any event, I would recommend that money be appropriated to provide for the printing of at least one thousand copies of all the Reports, and three hundred copies of all the Reports and Memoirs of the Survey, the same to be distributed, in part, to public libraries and men of science, and the remainder placed on sale in the hands of certain designated agents. The very limited means of the Geological Survey has hitherto made their distribution impossible.

If the Legislature will make a permanent appropriation, of as much as fifteen thousand dollars per annum, for the work of the Survey, with the understanding that the work is to be continued for ten years to come, and the work should be left in my hands, I can promise that, if the plans I have put on record are carried out, the Commonwealth will have a better record of its resources than has as yet been obtained by any State in this or any other country.

NOTES ON THE PROBLEMS ENCOUNTERED BY THE GEOLOGICAL SURVEY DURING THE YEAR 1877.

The various problems concerning the geology of Kentucky, which have been brought to the attention of its surveyors during the past year, will be, in due time, discussed in the several special Reports and Memoirs, where they properly belong. It seems, however, on many accounts, desirable that a brief account of these matters should find a place in the annual summary of the Director of the Survey. I will, therefore, make mention of a number of points of general interest, designating, when possible, the place where the several matters have received, or are to receive, a more extended discussion. It will be impossible, in a list of such diverse things, to preserve much system in the order of their succession; but, as far as possible, I shall give the economic problems the first place in the succession, taking the more purely scientific, or those of which the economic value is not yet apparent, for the second place.

The field work of the geologists of the Survey, though limited by the exhaustion of the appropriation, has not been without noteworthy results. Several of the leading problems which it has fallen to this Survey to consider have been elucidated, or, at least, have received some light by the labors of the past year. Of these, perhaps the information concerning the present and former limitations of the coal fields of the State is the most important. A careful search has been made to find the easternmost extension of the western, and the westernmost extension of the eastern coal field. I am satisfied that the other coal beds of the Chester series, or the beds just below the millstone grit, probably extend to the east of the Louisville and Nashville Railway, having their easternmost appearance at Frenchman's Knob, in Hart county. These coals, if found, cannot well have any economic importance. Wherever they have been seen by myself or my Assistants,

they have always been less than a foot, and not usually over six inches in thickness. These beds are the forerunners of the coal time, and really lie at a lower horizon than any workable coals that have been found in this country. It is not until about two hundred feet of later beds were deposited that we come to the time when the true productive coals were deposited. The true conglomerate beds are not found in position at any point east of the Louisville and Nashville Railway, until we come to the eastern field, though, as will be seen hereafter, its ruins cover a large part of the whole area between the two coal fields.

On the western face of the eastern field, the beds of the Chester series, or those belonging immediately below the millstone grit, find their westernmost extension in the mass known as Green River Knob, where they have a thickness of not far from one hundred and twenty feet. The thin Chester coals, that in Western Kentucky show that the coal forests had made their footing there at a very early date, appear to be wanting in Eastern Kentucky; so it is not probable that any coals whatever exist beneath this outlier of the Chester series. As the Green River Knob is much above the level of the neighboring country, overtopping by at least five hundred feet the other knobs of this district, it seems pretty clear that there is no chance of finding even the smallest outliers of the eastern coal field west of this point. In other words, it is pretty certain that, north of the Cumberland, and between the Louisville and Nashville Railway on the north, and the Cincinnati Southern Railway on the east, there is little chance of finding any workable coals, except, though improbably, in the extreme southeastern corner of this area, near where the Cincinnati Southern Railway crosses the Cumberland river. Here some small patches of the true coal measures may lie to the east of the railway; but this point is not yet sufficiently determined.

In this connection it will be well to call attention to the fact, that while the nearest outliers of the eastern and western coal fields are separated by fifty miles of interval, there is no doubt

that, at a comparatively recent time, in a geological sense, these two fields were connected together across the intervening space. The proof of this is found in the occurrence of the waste of the coal-bearing rocks on top of the various knobs and lower hills that covered the intervening space. On nearly all of these points we find the very characteristic and enduring pebbles of the Conglomerate abundantly preserved. On the higher points, where the outliers of the coal clung for the longest time, we often find the fossils of the coal-bearing rocks in fragments of the characteristic sandstones of that time. It requires the lapse of no more time, than has certainly passed away since the beginning of the middle Tertiaries, to account for the whole of the waste that has sundered these two fields. A fuller discussion of this interesting question will be found in the first volume of lesser Memoirs of the Survey now ready for the press.

The examination of the questions connected with the oil-bearing series of rocks in Kentucky have received considerable attention from the Survey. It is now pretty clear that here, as in other oil-producing districts, the profitable deposits are confined within a narrow vertical zone in this Commonwealth. No considerable quantity seems to have been obtained, except in that part of the section lying between the middle part of the Cincinnati Group, or the Blue Limestone and the base of the Devonian black shale, or, as it has been termed in these Reports, the Ohio shale. The conditions that seem to have brought about the deposition of oil in a workable shape in these beds are as follows: The Ohio shale, as is well known, contains a certain quantity of oil, the product of the slow decomposition of the organic matter of which it is mainly composed; but this black shale itself, being a dense rock, with few open spaces in its structure, either in the shape of rifts, or of spaces between the fine grains, such as exist in sandstones, there is no room for storage of any large quantity of oil in the shale itself; the result is, that the oil is forced beyond its mass, either towards the surface or towards some neighboring open-structured rock. As the production of the

oil is necessarily attended by the disengagement of a considerable quantity of gas, the oil is urged out of the shale where it originates with a great deal of force. Owing to this force, it invades rocks at some distance from the point of origin, driving out the water they contain, and filling the interstices with oil.

Now it happens that the district from the line of the Lebanon Branch of the Louisville and Nashville Railway, south, to the Tennessee line, and from the Cincinnati Southern Railway west, to a point some distance beyond the main line of the Louisville and Nashville Railway, the Corniferous limestone is pretty generally wanting, or is very thin, and the black shale rests directly upon the upper part of the Cincinnati Group. In this section the Cincinnati Group has for its upper member a rather fine-grained sandstone, which has received in these Reports the name of *The Cumberland Sandstone*. This sandstone is sometimes one hundred feet thick, though it does not usually exceed thirty feet in thickness. This bed probably contains the greater part of the workable oil of the State. So far, there is reason to believe that none of the wells that have yielded oil in quantities have been found in any other rock than this. Where, in this district, the black shale is immediately underlaid by a thick set of beds belonging to the Corniferous limestone age, or where the upper part of the Cincinnati Group is not composed of an absorbent sandstone, I do not believe that there is much chance of finding large deposits of oil. These favorable conditions are, I am inclined to believe, limited to the belt of counties that border the upper waters of the Green and Cumberland. Although it has not yet been possible to determine the line of these conditions in a clear way, I am disposed to believe that they will be found to prevail in the following counties: the southern parts of Rockcastle, Lincoln, Marion, and possibly Nelson; in Green, Taylor, Metcalfe, Monroe, Cumberland, Barren, Allen, Clinton, Wayne, Pulaski, Adair, Russell, and Casey. It may extend much further; but, so far, I have been able to obtain data for these counties alone.

Over this large area, including not far from three thousand square miles, or nearly one twentieth of the State, I am satisfied that it will be worth while to pursue the search for this valuable material. I do not mean to limit the chance of finding these oils to the district above described, but only to assert that, on the whole, this area seems to promise better prospects for success than any other part of the Commonwealth.

I am inclined to hope, despite the many unsuccessful trials that have already been made, that it will be possible to obtain a profitable quantity of coal oil from the beds of the Ohio shale itself. I have in preparation a more detailed statement of my reasons for this anticipation than I can give here without unduly swelling this report. I may, however, say, in brief, that, by changing the character of our wells—making them with the diamond drill, or in the shape of ordinary pit wells—it will be possible to secure a freer ingress of oil from the compact strata in which it is lodged. So far, all our wells have been opened in the old fashion, by means of what are called driving tools—acting by the impact of a falling punch or drill. This method opens but a small tube, and compacts the walls of that tube in a very objectionable way. This packing of the walls often much restrains the natural flow of oil into a well. I am disposed to believe, that, in many cases where oil has been found in quantities too small to repay the labor of collecting it, wells of larger wall-surface, and bored with tools less apt to smear the sides of the opening, might have succeeded much better. In other cases I believe that the ordinary well, such as is dug for water, will be found to be more successful than any other form. It has been used for centuries in India. In our dense rocks, where the amount percolating into a tube three to six inches in diameter would be unprofitably small, a well five to ten feet in diameter, with perhaps horizontal galleries pushed off into the oil-bearing rock from the bottom of the shaft, would, perhaps, prove remunerative. In this way a percolating surface, several hundred times greater than that secured in a bored well, could often be secured, at an even less cost than a well of the last-named description. It is

hardly necessary to say that it would be important to take precautions against the damage from the gas which abounds in our oil-bearing rocks; but, by using a forced ventilation, and only "Davy" lamps, or by obtaining light from the surface sent down the well by means of reflectors, this danger would be obviated. Of course, this method would only be available when the depth of rock to be penetrated was not too great; but, up to depths of one hundred to two hundred feet, I should deem it quite worthy of consideration. Over a large part of our promising oil district the depth of the productive rock does not exceed the distances named above. This matter will be found more fully discussed in the Bulletin and the forthcoming Reports of the Survey.

The work of discovering the various marls and limes of the State, that may have a value for agricultural purposes, has made some progress. A glance at this question will show its great value, and I venture to ask the reader's attention thereto for a moment. The wide differences in the soils of our State are well known to all observant persons. It often happens that, in passing a few hundred feet across the surface, the character of the soil, as shown by its appearance, its native timber, or its crops, is radically changed. This change is always found to connect itself with the alteration of the character of the underlying rocks, and is immediately brought about by the coming of new deposits to the surface. It is, therefore, to be expected that we should find the chemical constitution of these rocks to differ widely the one from the other. This fact is so well known to geologists, that it would not deserve mention on account of its novelty.

The researches of the Survey have, however, gone further than this, and have shown that the fertility of a given district is often closely dependent upon the material furnished by one or more thin beds of exceeding richness in certain constituents. In the blue-grass district, for instance, the greater part of the rock section gives us no exceeding store of the materials most necessary to make a fertile soil; but we find certain thin beds which, under analysis, show an extraordinary richness

in the various important ingredients of our soils. This is well illustrated by the discovery, by Dr. Peter, during the past year, on the Newtown Pike, near Lexington, of a thin bed, probably not exceeding six inches thick at any point, which shows, under analysis, as high as thirty per cent. of phosphoric acid. This discovery, being very recent, it has not been possible to trace the beds in question over any wide area; but I am satisfied that, owing to the fact that they were evidently formed in deep water, they cover a large part of this most fertile district.

It will be the aim of the Survey in the future to follow out this inquiry, and examine all our soil-producing rocks, and to find to which beds the soils of a given district owe their peculiar qualities. This examination will have for its result the identification of the marls or limestones to which we must look for the enrichment of our impoverished fields.

In making this important investigation, there are two distinct lines of research that can be followed, and it will show the intimate way in which the most abstract scientific problems are closely identified with the practical questions of our every-day life. These two methods are as follows: In the first place, we may proceed to select specimens of each and every distinct bed of rock in the State, and subject them to analysis, which would be a very costly and tedious process, or we may take the more certain plan of determining the agents that bring about this fertilizing character in marls, and so, perhaps, obtain simple indications that, by showing the chemical nature of the mass, spare the costly researches of the laboratory. There is hope that we may attain to this simpler method of inspecting our rocks, or at least be able to get indications that may be followed up in the chemist's laboratory. Recent researches, in which the laboratory of the Survey has had a large share, make it plain, that, in most cases, the fertilizing power of marls, &c., depends on either of two things, viz: 1st. On the richness in fertilizing materials of the older rocks from which the beds were derived, and the subsequent concentration or diffusion of these valuable substances in the re-making of the rock. 2d. On the amount of the

remains of certain species of animals and plants in the deposit. In illustration, I may cite the case of two of our newly-discovered marls, which I deem of value. The *Leitchfield Marl*—that bed occurring in the Chester Group, containing a considerable charge of potash, soda, and phosphoric acid—is a good example of the first division, or that where the richness in fertilizing materials is due to the substances derived from the old rocks whence the sediments making up these marls were deposited. These Leitchfield marls are doubtless the product of the decay of granitic rocks—the felspar and mica furnishing the soda and potash we now find in them. The process of breaking down the old granite of the Carolina and Canada Mountains, and bringing its ruins into the sandstones and marls of the Chester limestone, has resulted in concentrating the potash, soda, and phosphatic matter into much less space than it occupied in the old beds.

In the case of the thin but exceedingly rich marl found on the Newtown Turnpike, near Lexington, the great store of phosphoric matter is due entirely to the accumulation of the waste derived from certain species of invertebrate animals, and is not, in the least degree, to be attributed to the store derived from older rocks. By carefully studying the various rocks of the State, either by the naked eye or by the microscope, it will be possible to determine, with great certainty, which of them promise, by their structure, to afford valuable elements for our economic uses.

It is in such work that we see the close relation between the most recondite branches of science and the matters of the purest utility. At first sight, it would seem that the question of the structure of the living beings that held their place on the ancient sea floors was of infinitely small consequence from a practical point of view; but when we consider that the fertility or infertility of our rocks depends upon the work done by those creatures, in taking the elements of fertility from the sea water and laying them together on the sea floor, we readily see that this inquiry may have the greatest value to the economist.

The crops of our fields often depend for their growth upon the work of the creatures of the distant ages of the earth's history; and in tracing the economic marls and the limestones suited to the use of the agriculturalist, we cannot avoid investigating the creatures to which they owe their stores of fertilizing materials.

The researches made upon our building materials during the past year have had some important economic results. In this field, more than any other, have I been surprised at the wealth of the State. As yet, nothing of importance has been done to develop these resources. A sufficient examination of building stones requires a considerable time; some of the tests, indeed, can only be made by exposing the particular specimens for some years to the ordinary conditions of the atmosphere, and observing the resistance they offer thereto.

All the building stones of our State can be brought within the simple classes of limestones and sandstones. In the limestones we have an exceeding variety of valuable stones. I am satisfied that our country does not exhibit, in any other region of equal area, a wider variety of characters in its building stones than is found within this Commonwealth. In anticipation of the regular reports on the building stones of the Commonwealth, I will indicate some of the principal groups of stones which seem to me to have an unquestioned value, and to be well deserving of introduction into our markets.

Taking first the limestones, we may note the beds in the order of their succession, from the lowest to the highest rocks in our section.

The lowest lying rocks are those of Upper Cambrian age, in the level commonly known as the horizon of the Bird's-eye and Trenton beds. Along the Kentucky river these beds give the well known Kentucky river marbles—blueish, yellowish-buff, and grey limestones of great resistance to the action of the weather, and easy to work. These are too well known to require mention here. I will only say, that this is apparently the only point where, within the Ohio Valley, the rocks of this level come to the surface. So far, these particular kinds

of stone in this Kentucky river district should have no competition.

The building of the Cincinnati Southern Railway to and beyond this river, makes it possible to secure a ready transportation for those stones to large markets. The construction of an inclined way to the level of the river, at the point where the railway crosses, would make it possible to open quarries with good chance of a market. The proper development of these building stones will, however, require the locking and damming of the stream on which they lie.

The next higher level, that of the rocks in the bed of the river at Cincinnati, gives us a very argillaceous, blue-colored, durable limestone, which has been extensively used about Cincinnati for underground work, for which its eminent durability commends it, and which has also, in some cases, been used for finished front work. This rock is possessed of admirable qualities, and, though of no great beauty, is of great value in all places where endurance of atmospheric action, of fire, and of pressure, are required. At Cincinnati, this bed is in the bed of the river. About ten miles above that city, the rise of the beds carries it up to the level of the alluvial terrace, where it is not very accessible, but it could be found along the banks of the creeks, a little way from the river. The rise of the beds brings to the surface of the water, along the banks, a set of rather thick-bedded reddish-grey limestones, very well fitted for ordinary ornamental work or house work, though perhaps of rather sombre colors. In the hills bordering the river, between Maysville and a point say thirty miles above Louisville, the Cincinnati Group contains in its upper members a well-known set of semi-crystalline, dark-colored building stones, which have been very extensively used for ordinary stone work. When laid with care, these stones are of absolute durability, and are much freer from brittleness than many of our limestones. Near the top of this series is possibly found, in the central district of Kentucky, a rather massive, argillaceous, arenaceous limestone, which, in the region near Mt. Sterling, is perhaps too soft for working, but at certain other

points furnishes a good building stone. The rock was used in the construction of the court-house at Paris, Kentucky, with success. Going south of the Kentucky river, towards the Tennessee line, the upper part of the Cincinnati Group of rocks changes gradually to a sandstone of a greenish hue. In the recent reports of this Survey, this has received the name of the Cumberland sandstone. Owing to its remoteness from transportation, this interesting stone has received but little attention. I have seen a few walls made of it; but these were not of a nature to test its durability or the other elements of its architectural value. Its very handsome color —greenish-yellow verging to a blue-grey—its softness, and its freedom from all changes caused by weathering, inclines me to think that it may prove a valuable stone. Its most extensive development is along the banks of the Cumberland river, above Burksville; but it is found throughout the district south of Muldraugh's Hill, wherever the upper part of the Cincinnati Group comes above the drainage. I have seen the deposit about thirty feet thick in some parts of this district; but, as yet, too little study has been given to this bed to make it clear just what are the limits of its distribution.

About this level we have, in the horizon of the Niagara limestone, some beds of rock that promise well as building stones; but this formation is only distinctly marked in certain parts of the State, and is generally quite thin, so that search for these beds cannot be recommended.

The next horizon in the ascending series is that of the Corniferous limestone. This set of rocks is that found in all parts of Kentucky. It is wanting in most if not all of the region drained by the Cumberland and the Green rivers. It is found, however, around almost all of the border lands of the blue-grass belt. In Jefferson county it forms the falls of the Ohio. It has been seen in the counties of Jefferson, Bullitt, Nelson, Marion, Lincoln, Rockcastle, and Madison. Wherever found, it will furnish valuable building stones, especially those desired for decorative uses. Several of the beds of the falls limestone would make marbles of admirable richness of detail and

beautiful colors. I am greatly surprised that, with abundant water-power at hand, these stones have not been quarried at this point, and polished, as they could be, at small cost. At the falls of the Ohio the Corniferous limestone is a reef of corals, and its beds are crowded by organic remains, principally corals, so that they are very handsome when exposed by cutting and polishing. In its more southern extension, the beds of this Corniferous series become less coralliferous, but still are, to a great degree, limestones made up of this class of forms, which are very beautiful when shown in a polished section. In Lincoln county this rock becomes changed to a breccia; that is to say, the rock appears to be composed of angular fragments cemented together by a substance of a different character. In this district it is an arenaceous limestone, and would make a handsome building stone; in some parts of the district it is probably suited for polishing. It is pretty well shown, where it is crossed by the Cincinnati Southern Railway, at a point a few hundred feet north of McKinny's Station, in Lincoln county. The origin of this peculiar brecciated structure will be discussed in the first volume of the lesser Memoirs of this Survey.

The Devonian black shale, often called, in these Reports, the "Ohio shale," is the only extensive series of deposits known to me in the Commonwealth that affords absolutely no building stones. All the beds are usually of soft materials. Sometimes a thin bed of limestone will be found intercalated among the beds. This is but rarely, however, and the beds so found are mostly in patches, and worthless for any economic uses.

The next series of rocks, the Waverly sandstone or Keokuk Group, is, of all our Kentucky rocks, the richest in good building stones. On the Upper Ohio, in Lewis and Greenup counties, it is extensively developed. In the six hundred feet occupied by its beds there are several excellent sandstones, which have already been extensively worked, both in Kentucky and Ohio. These stones are admirable for their softness and resistance to ordinary atmospheric action; but they

are apt to be stained by exudations of petroleum and of iron. There are some limestones in this series along the Ohio river; but they are very arenaceous, and none have been observed that recommend themselves for use. As we go south and west from the Ohio, along the outcrop of this series, we have the rock gradually changing to a soft shale, crowned near its top by some rather incoherent limestones and sandstones. It is this shaly element, which is readily assailed by the agents of decay, that causes the outcrop of this formation, in its more southern exhibition, to be bordered by knobs or isolated prominences of its mass. Scattered along the outer face of this formation we find hundreds of these castle-like ruins, that attest the speed with which the destroying forces work upon its little resisting rocks. When, in going westward, we pass the line of the Cumberland and Ohio Railway, we suddenly find ourselves in a district where the nature of these beds is again subjected to a change. We then have the shales changing to limestones; and by the time we come to the line of the Louisville and Nashville Railway, the upper two hundred feet of this formation is nearly all of a calcareous nature. These beds are fairly well exposed in the sections made by this railway, where it climbs the steep face of Muldraugh's Hill, in the five miles between Colesburg and the tunnel at the top of the escarpment. At a number of points on this line the beds could be advantageously worked for building stones. They are magnesian and Silurian limestones, and vigorously resist decay, as may be seen from the natural faces, or from the waste of the excavations of the railway, left exposed for thirty years to the action of frost, sun, and rain. At sundry points the rock could be obtained with relatively little stripping of overlying earth and shale.

Along the Green river, especially near the crossing of the railway and the Nashville turnpike, the Waverly rocks—for such I deem them—despite certain doubts as to whether they may not belong to higher measures in the Sub-carboniferous series, afford beautiful building stones, and some, by their brecciated character, well suited for decorative purposes; warm,

reddish-colored stones, or those of a pleasant buff color, abound in this part of the section. Small polished fragments make an excellent showing, and promise beautiful effects whenever larger masses are dealt with.

Again, in the district south of Franklin, in Simpson county, on the line of the same railway, we have other exposures, which appear to belong to the same series, and which furnish promising quarry rocks. At West Point, on the Ohio, we have other exposures of the rocks of this section, which are more of a purely limestone nature than in the eastern sections. Thus we see that this formation affords us, in its easternmost exposures, excellent sandstones, and in its western conditions a wide range of limestones that promise well for exploration.

The next higher set of rocks in the series are those known as the Warsaw and St. Louis limestone beds, which, though separated from each other in their western development, are not very distinctly divided in this district, affording a limited range of materials, but including two or three of the most valuable quarry rocks as yet found in Kentucky. Of these, the oölite, known as the Bowling Green stone, alone has found a place in our markets. Except the Buena Vista sandstone from the Waverly series, on the banks of the Ohio, this stone has been the most extensively shipped to distant markets of any found in the Commonwealth. So far, the only extensively quarried rock has been the oölite, from near the middle of the St. Louis limestone. In this part of the section the rock is very generally oölitic, or composed of small spherical masses of limestone, closely resembling, in general appearance, the roe of a fish; hence the name. The rock is generally white or greyish in color, and is very massive, even, easily cut, hardens on exposure, and is absolutely durable in a way that no other rock found in the Ohio Valley can be said to be. The only quarries now producing this stone are near Glasgow Junction and Bowling Green; but equally good stone, if anything, whiter than that from further south, can be obtained nearer to Louisville. Close to the crossing of Green river

the rock is very well shown, in many places, along the line of the railway. For all the purposes of the architect, I know of no stone that surpasses this admirable material. I look forward to a very extensive use of it in the Mississippi Valley. So far as my knowledge goes of this peculiar quality of stone, it is not found beyond the bounds of Kentucky.

Other beds in this formation, of the ordinary limestone structure, afford good building stones for the commoner uses for which such materials are required; but none others of peculiar value have as yet been examined.

The next series is that of the Chester sandstone. This affords some sandstones which have not yet been brought into use, but are not unpromising in appearance. The beds along the Big Clifty creek, on the line of the Elizabethtown and Paducah Railway, exhibit the general character of these measures, where they are found in Western Kentucky. In Eastern Kentucky, where found—for it is not known to me north of the Kentucky river—this rock is a very soft, reddish sandstone, not promising as a quarry rock, though in some places it may attain sufficient hardness for certain uses. The best exposures of this rock known to me in Eastern Kentucky is on the upper part of the Green River Knob, in Pulaski county, where it is too soft for building purposes.

The coal measures contain very few useful building stones. Some of the Conglomerate sandstones, at their base, are reasonably hard, and withstand the weather well. In Western Kentucky, as along the lower waters of Nolin river, these rocks are very extensively developed; but they occur at the base of almost all of the coal measures in the State. Generally, however, the rock is soft within, however hard it may appear upon the surface, and crumbles badly in the quarry; though, once in position, it can be trusted to become more and more solid as time advances. In the middle part of the coal measures there are, particularly in Eastern Kentucky, some very good building stones; though none of them are very hard. They are all sandstones; for while occasional beds of limestone do occur, they are all, so far as known to me, of

little value for building purposes. The rocks in Western Kentucky, belonging to the Tertiary series, do not, so far as known to me, afford any materials suitable for building stones.

It should not be supposed that the search for the available building stones of the State is by any means complete. Not one third of the work of reconnoissance for these materials is as yet fairly done, and we may reasonably expect many other important additions to this brief list of varieties.

The forests of the State have received their share of attention during the past year. Though the work is hardly more than begun, this Survey has done more for the accurate detailed study of our forests than has hitherto been done in this country. The aim of this work of the Survey, hitherto, has been to secure an accurate statistical account of the forests of this Commonwealth. Where its work has been completed, the reports exhibit just what each county contains, in the way of timber, with such accuracy that its precise commercial value may be estimated from the description alone. To accomplish this, it has been found necessary to construct accurate tables setting forth the exact number of trees of particular kinds on specimen acres of each district. It is also necessary to set forth the size and condition of all these timbers, the nature of the soil and subsoil on which they have grown, the character of the underlying rock, &c. Further than this, I have urged upon my assistants the desirableness of making a careful inquiry into the condition of the underwood or young trees. There are many results promised from this method of inquiry, most of which are, as yet, too undeterminate for description here. The following points, however, are so important and so well determined, that I venture to call public attention to them:

The white oak, by far the most valuable of all the timber trees found in Kentucky, has been made the subject of a careful study by my valued assistant, Mr. L. H. DeFriese, from whose observations it appears that this species is likely to become practically extinct in many districts, if not throughout the State, within a century or two, owing to the nearly com-

plete absence of young trees in our forests. I refer those interested in this question to the admirable reports of Mr. DeFriese, contained in the second and fourth volumes of this series of reports, published in 1877. It will be seen that Mr. DeFriese has not based his determinations on casual inspection, but upon extensive and carefully made statistics, gathered from large areas of forests in different parts of the State.

It seems to me, from these facts, quite beyond question, that there are natural forces at work tending to replace our white oak forests with the comparatively worthless black and red oaks. As yet, this inquiry has not gone far enough to make it clear to just what cause this peculiar succession of timbers is to be attributed.* It will probably require some time to determine this important question; in the meantime, it behooves our land-holders to consider whether it is not worth their while to provide against the scarcity of valuable construction timber in the future, by planting this and other species of hard-wood timbers in our forests or in special plantations. It is hardly too much to say, that the future prosperity of the manufacturing industries in this country will depend largely on the supply of wood of this description. Those who desire to leave to their heirs a property of a perfectly certain nature, to which time can only give continually increasing value, may be assured that no other property can give such security of constant increase and safe-keeping.

There are hundreds of thousands of acres, of well-conditioned forests within the Commonwealth, that can be purchased for prices ranging from fifty cents to five dollars per acre. A small annual expense given to the girdling of worthless trees and the planting of valuable species would, in a few years, make these forests nurseries of the species of timber that bring the highest prices in our markets. There are also very extensive areas of impoverished lands, the superficial soil

*The cause of this disappearance of the white oak will be discussed hereafter in one of the forthcoming papers in the 8vo. series of Memoirs. I may venture here to suggest, that one of the causes is probably to be found in the fact that the acorns of this species are sweeter than those of other species of oaks, and are probably more generally eaten by the squirrels.

of which has been worn down in the reckless cultivation of exhausting crops. These cleared lands can often be had for less than the cost of clearing virgin forests. They will, as is well known, afford excellent places for timber-planting. Black locust, cherry, walnut, ash, larch, osage orange, and many other species of valuable trees, can be readily rooted on these wasted soils. At the present prices of these timbers it is easy to prove that, at the end of thirty years, the aggregate return will give an average interest of from ten to twenty per cent. on the investment, after making all allowances for accidents. Although this class of investments may not commend themselves to that momentary greed of our time, which has so far replaced the sterner and sounder business instincts of our fathers, yet I hope that they may commend themselves to the broader discretion of corporate associations. I venture to suggest, that a certain sort of insurance companies could safely be founded on such investments. A company, organized with a capital of sufficient size, agreeing to pay no losses for fifteen years from its date, but then to pay a pro rata on its receipts, would offer an attractive form of investment to that limited class that desires in the flower of youth to provide for the chance of declining years, or to make provision for new-born children when they come to the needs of those years in which the beginnings of independent life are made. I feel that it is safe to say, that money sagaciously invested in improving existing forests, or replanting waste lands, would be found to yield a larger return than in any other well-assured investment.

In a forthcoming number of the bulletins of the Survey, the economic importance of this interest will be discussed, and such suggestions as have been obtained from the studies of the Survey will be considered in some detail. As soon as the reports of the gentlemen charged with the study of our forests have been brought to completion, they will be assembled in a single volume, entirely devoted to this important class of problems. What may be called the indirect value of our forests has not been left out of mind. In this group of questions

I include the effects of forests upon rain-fall, upon temperature of seasons, and upon the storage of water in relation to our rivers. With the view of directing attention to these questions, I have, with the permission of the author, inserted, in an Appendix to the Report for the year 1875, extensive extracts from the valuable work of the Hon. G. P. Marsh, entitled "The Earth as Modified by Human Action."*

If it is the pleasure of the Legislature to extend the operations of the Survey over a number of years to come, I hope to take up the study of these problems in a detailed way.

I have repeatedly stated my strong conviction, that this Commonwealth is profoundly interested in this question of forest administration. I am, moreover, satisfied that no part of this country is, on the whole, so well placed for a careful discussion of the questions that are involved therein. We have a greater range of conditions than is found in any other equal area, and the chance of obtaining accurate data is better here than it could be elsewhere. This inquiry is, however, of such nature that it will be necessary to extend it over a long term of years, though the annual expense need not be large. I have not made any estimate for the work, though, in the existing laws controlling the action of the Geological Survey, there is provision made for a certain amount of study of our forests. It has seemed to me, however, desirable to complete the preliminary studies of the State, to get the topographical and geological maps of its surface well advanced, and the study of the actual nature of our forests completed, before this branch of the Survey work should be undertaken.

I have, however, kept before the topographers of the State, as one of the problems involved in the study of our forests, that loss of water-storage power in the country arising from the thinning out or the utter destruction of extensive forest areas. It is a well known fact that many streams, that once were in steady flow throughout the year, are now torrents in the rainy seasons and dry ways in time of drought. In the

*I am especially indebted to the illustrious author for sundry emendations of this work, which have been incorporated in these extracts.

early days of the country, the beaver formed thousands of dams along our streams, which retarded the passage of the water to the sea; the same work was done by fallen trees and by the mat of the forest bed. It is clear that these old restraints upon the outflow of water, from the higher parts of the country, must be replaced by some contrivances of the engineer, or our streams will lose their proper character as rivers, and become, in the successive seasons, destructive torrents and shrunken or stagnant streams. Although this problem of water-storage cannot be advantageously discussed until good maps of the State are in hand, it should be continually borne in mind as one of the objective points of the Survey. It is probable that this problem will have, in the end, to be taken up by the Federal Government, inasmuch as it is too extensive to be dealt with by a single State. It is, however, in the power of the States to gather the data on which the Federal Government can base its action.

I have now to speak of another branch of the inquiry made by the Survey, which has an immediate value. The Centennial Exhibition brought clearly to my attention the great value of the pottery clays of this district. Our area abounds in materials well suited to the special needs of the potter; and as this industry, the first of the arts of man after the invention of weapons, is, and always must be, one of the most extensive employers of capital, labor, and fuel, it is well worth our while to do what can be done to attract it to our State. In the furthering of this purpose, the Survey should make a careful study of the various clays that are found within the State. A good deal has already been done to collect and analyze specimens of these deposits; but while the laboratory tells us much concerning these clays, more remains to be determined by the practical tests of the potter. Clays are, in their nature, so variable that this must be an extensive and troublesome inquiry, and in its making I must seek the aid of such potteries as are already in existence within our State, or near enough to its borders to be interested in the development of its resources of this nature. Very extensive collections of our

clays should be made. As they all owe their origin to the decay of older rocks, and have generally been specially modified by the action of local agents, they cannot be considered in the same general way as many other beds. It will be necessary to collect, in each limited district, samples of such size as to give a good basis for a practical test of the qualities of the particular variety of clay. For this, about one hundred pounds will be necessary. For the guidance of those who may feel inclined to aid the officers of the Survey in securing these collections, I will briefly set forth the nature of the localities in which they may be advantageously sought. In this description a simple classification may advantageously be employed.

ANCIENT CLAYS.

These should be sought in all the rocks that are found in the State, from the lowermost, along the Kentucky river, to the Tertiary beds of the bluffs along the Mississippi. Wherever a bed possessing the general qualities shortly to be described exceeds four feet in thickness, and is otherwise well placed for working, it is worthy of note. This group of clays, though varying much in general character within a range of a few miles, will be found more constant than the second class. They may be divided into two subordinate groups.

a. Old Marine Clays.—These are the ordinary clays of our rocks. To these belong all those found in the blue limestone series.

b. Old Land Clays.—To this class belong the fire-clays of the coal series, always, or nearly always, found beneath coal beds, and constituting essentially the soil in which the vegetation that composed those coal beds fixed its roots.

c. Lacustrine Clays.—To this class belong, alone, in Kentucky the clays found along the borders of the Mississippi river in the so-called Chickasaw Bluffs. These were doubtless laid down in the fresh or brackish water of a great estuary or lake, and so have essentially the character that fresh water stamps on all deposits made within it.

The next class of clay beds may receive the name of

RECENT CLAYS.

These are all the product of very recent geological actions, and, unlike the preceding rocks, which were mostly derived from the waste of rocks beyond the limits of the State, are from the waste of the rocks within its borders. These deposits are limited to three simple kinds, which may be briefly described under the following heads:

River Clays.—These are found in the terraces along our existing streams. They are very varied in their character, and, though generally rather sandy, are often of excellent quality. They may be sought to advantage along all of our large streams, especially the Ohio, where a number of promising clays have already been found. The probability of finding good pottery clays increases as we descend the Ohio or other main streams. The fineness of clay is in the inverse ratio to the rapidity of the current of the stream that deposits it; hence, inasmuch as the nearer the mouth of the stream the weaker the current becomes, it is in the lower part of the great valleys that these finer clays should be sought; moreover, since the head waters of all our large Kentucky rivers lie within sandstone districts, and only drain extensive deposits of fine-grained rocks in their lower waters, it is naturally to be expected that fine sediments should only be found in the lower part of their valleys.

In search of these clays, attention should be given to the several different levels of terraces found along our rivers. I am inclined to believe, from my experience in search of these clays, that they will be more often found of good quality in the upper than the lower terraces. At various sections along the Ohio I have failed to find any very fine-grained clays in the belt of land below the top of the highest water, while the next level, rising say ten feet above this high water-mark, contains very generally, in the district near Covington at least, a blue-grey clay that will be useful in making all the ordinary kinds of pottery.

Pond Clays.—This very limited group of clay deposits is principally, if not altogether, found in the sink-holes or the

funnel-like openings that lead downward into the caverns of the limestone areas. These openings exist in numberless profusion within the State. Certainly not less than half a million of them, averaging an area of half an acre each, may be found in the Carboniferous limestone district alone, and nearly as many in the blue limestone area. Not infrequently these inverted cones contain several acres. I have seen them, in some districts, covering ten acres or more. As long as the openings draining these sink-holes remain open, there is, of course, no deposition of clay within them; but they often become closed by accidental causes, and, by a very little labor, it is easy to close them. When closed, a pond forms in them, and they begin to be places of deposit. As there are rarely any running streams finding their way into these circular pools; they receive only the very purest sediment from the neighboring land, such as can be borne by the slender rivulets that find their way, during each rain, into the pool. These pools are, in a word, just such basins as are often used in the arts to obtain the finer pottery clays free from coarse sediment. I can recommend a search among the sink-holes of the State for clays of this description required in pottery works.

Cavern Clays.—These deposits are similar to those found in the sink-holes or upper mouths of the caverns. They give the same favorable condition for the formation of fine clays, but often in a superlative degree. These clays are frequently much more accessible than would be expected from the circumstances of their occurrence; and I expect, when the economic value of our clays becomes practically established, they will in some cases be sought for with profit.

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SCIENTIFIC PROBLEMS.

Following the plan that has hitherto guided me in making my summarized annual reports, I shall now proceed to set forth briefly the outline of the more important and purely scientific matters that have come to my attention during the past year. In many cases, the abstract questions of importance are so bound up with the more practical matters, that they have already received the brief mention that belongs to them in this summary. Of these, I may instance the origin of coal oil, which is at once a matter of the highest economic and scientific importance. On this point the work of the Survey has thrown some little light, by a study of the conditions of occurrence of the substance in certain localities.

Again, in the short account of the building stones of the State, given in former pages of this Report, I have called attention to the peculiar westward change of the series of rocks known as the Waverly sandstone, which is gradually changed, first into a series of shales, then into limestones as we pass to the west, becoming, in Western Kentucky, a tolerably pure, somewhat cherty limestone.

The scientific work of the Survey has been kept entirely subordinate to the economic work; so that the results obtained of a purely scientific nature have been reached in a rather accidental way. Most of them are in a too fragmentary state for any form of presentation; so that I shall only note a few of the more important and more complete.

Perhaps the most valuable result of the year's work, in a scientific way, is found in the facts that have been gathered, going to show the former existence of a complete union between the eastern and western coal fields, across the region now occupied by the upper waters of the Green and Cumberland rivers. A treatise on this subject will be found in the Memoirs of the Survey. I will here only note, that the gap between these fields, now only about sixty miles in breadth, is occupied by the waste of old coal-measure rocks that cap

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nearly every high hill. The pebbles of the Conglomerate, which are peculiar in their nature, and easily recognized, are found on every high point in this district; and in many places the fossil plants of the coal-bearing rocks have been found, showing quite incontestably the former existence of the beds whence they were derived over this area. Less distinct, but very suggestive evidence, has been found, leading us to raise the question whether the coal measures did not cross over the district near Lexington, bringing measures of that age into contact with the rocks of a much earlier age. Much evidence yet hidden will doubtless reward the prosecution of our researches; but enough has already been obtained to warrant the opening of this broad question.

Incidentally, some study has been given to the ancient coral reefs of the palæozoic seas, of which there are several within the bounds of the Commonwealth. Besides the general interest that belongs to this curious type of structures, as the great physical monuments of life, beside which the mightiest structures of man become insignificant, there are various special questions that they bring before the student. The set of currents in the ancient seas, the temperature of the water and its depth, can all be determined by the position of these buried reefs.

Of these reefs, the only cases that have been studied are those of the Ohio falls reef in the Corniferous limestone, and that of Nelson county in the Cincinnati Group. The former, perhaps the most conspicuous of all the American palæozoic reefs, has distinctly the character of a barrier reef, and extends for many miles along the west face of the Ohio Island, as I am disposed to term the uplift commonly designated as the Cincinnati axis. Throughout the greater part of its extent this reef is hidden beneath the overlying deposits; but enough is known of its extent to make it plain that it must range for some distance to the north and south along the line of the old island. Its diameter, in an east and west direction, is not readily ascertainable. I am inclined to believe, however, that it is comparatively narrow.

The region within this reef, or on its eastern side, seems to have contained relatively little life. The deposits therein appear to be of a sandy nature, and are often quite without fossils. On the eastern face of the Ohio Island there appears to have been again the seat of a tolerably abundant life; but though corals occur rather plentifully, they never form a true reef on the eastern face. The only other distinct coral reef, that I have yet been able to trace in Kentucky, is found in the upper part of the Cincinnati Group. As before remarked, in the description of the oil-bearing beds in the Cumberland River district, these beds, which are tolerably blue limestones in the district north of Harrodsburg, south of that line generally become sandstones. The presence of these limestones indicate that the shore line of the ancient seas was nearer to the southern than to the northern line of the State.

On the western border of this district, where the Cincinnati section is converted into arenaceous sandstone, there is a great coral reef, resembling, in many respects, that before described at the falls of the Ohio. The former reef is obscurely indicated in the sections near Louisville; but it increases in depth as we go southward, until in Nelson county, about ten miles southeast of Bardstown, it is about one hundred feet thick. At this point its course seems to incline rather to the southeastward; but its precise course is not readily traceable.

This reef, which I propose to call the Nelson reef, is composed of an entirely different association of corals from that which occurs in the Louisville reef. This very great difference in the character of the life in reefs, that closely succeed each other in time, is a matter of great interest to the geologist. It points to wide-spread changes in the physical conditions of this region, in the time that intervened between the period of the Cincinnati Group and the beginning of the Corniferous limestone.

In examining this reef, an interesting discovery of some peculiar fossil remains was made. Whoever will examine the exposed beds of this deposit in Nelson county will see, in favorable localities, the surface of the ground thickly strewn

with fragments of a large coral-like fossil, the stems of which break into columnar fragments six inches or more in diameter and a foot or two long. It is easily seen that they are the remains of an organism that built stems, in the fashion of short limestone columns, several inches in diameter and perhaps ten feet or more in height. These curious fossils were first discovered in 1858, on the island of Anticosti, in the Gulf of St. Lawrence, and were described as corals, under the generic name of Beatricea, by the late Mr. Billings, of the Canada Geological Survey. I have elsewhere expressed the opinion that they are more likely to be sponges than corals; but the interest of the discovery does not depend on the nature of the animals that built these remains, but rather on the fact that, existing in great abundance within the Anticosti and the Nelson county localities, they have never been found at any point in the intermediate district. When we consider that beds of the same age in New York, Pennsylvania, and Ohio have been searched with exceeding care for these fossil remains, the absence of this, the most conspicuous fossil of all these ages of the palæozoic time, must be taken as proof of its limitation to these two widely separated points. This is but one of the many cases that could be adduced from the fossils of this time to show that the localization of fossils in a narrow field is by no means a peculiarity of the more recent times in the earth's history, as it has been by some assumed to be.

The physical structure of our rocks has given suggestive information on various questions of importance to the geologist. Two or three of these inquiries have been carried far enough to yield some results. The first concerns the formation of the peculiarly broken and re-cemented rocks commonly known as breccias. The present opinion concerning these re-cemented rocks is, that they were all formed by the violent rupturing of the rocks, and the subsequent re-cementation of the broken bits by the action of infiltering waters. A careful study of our Kentucky rocks has shown me, that certain breccias may be formed without the intervention of any disrupting

violence, such as has always been called into account. We have in our rocks the frequent case of brecciated limestones, lying between beds that exhibit no trace of this structure, and show, moreover, by their conditions, that they have never been affected by agents of violence. The explanation of this peculiar structure may be given in a very few words.

In the first place, it is to be noticed, that, in the same series of rocks where this brecciation is most apparent, geodes abound. These crystalline spheroids are very often formed from a crinoid head. This fossil, as is well known, is composed of a series of plates joined together as the tiles in a pavement. In the joints between these plates the deposition of crystalline matter begins, and the plates are gradually forced apart, until they are upon the surface of a hollow sphere, perhaps three or four times the diameter of the original mass. In the same set of rocks we find a breccia where the angular fragments are pushed apart in the same way, showing that the action that forms these particular geodes is essentially the same as that which forms the veins that separate the bits in the breccia. In both these cases, the result is to bring to bear a very great pressure upon the rock when the geodes are forming; for this expansion of the crystallizing hollow sphere necessarily results in pushing aside the neighboring materials. The geological effects of these pressures upon the beds in which they are brought about are far-reaching, but cannot be inquired into here. Their discussion will be undertaken in one of the forthcoming papers of the Survey, which will be found in the second volume of its quarto Memoirs. It is hardly necessary to say, however, that this peculiar phenomenon has an important bearing on the theory of mineral veins. The idea that such veins are necessarily pre-existing crevices, into whose free spaces matter is introduced in solution, and there crystallized, will have to give way to the opinion that, in certain kinds of veins at least, it is the crystallizing action itself that disrupts the walls of the cavity in which the vein-stuff finds its lodgment.

While this class of facts seems to show that certain of our Kentucky rocks are acted upon by forces which tend to make them occupy greater spaces than they now do, evidence is given us that some of our rocks are still much acted on by forces that impel them to occupy less space than they have hitherto done. I will briefly describe the most notable proof of this kind that has come to my attention:

In the middle of June of this year, while I was in Stanford the county seat of Lincoln county, I learned that, on the second day of that month, the beds of rocks in a small tributary of Dick's river, a few miles northwest of the town, had been suddenly rent, and upheaved into a low broken ridge. On visiting the place, I found the following facts:

The bed of the creek lies in the upper part of the Cincinnati Group, or Blue Limestone series; but at this point the series is much less calcareous than in the region to the northward. The rock lies rather in thin beds, but very compact and dense—rather arenaceous and calcareous—showing a remarkable want of the open joints so common in many of our limestones of this series. Below the level of these hard beds are limestones which show the ordinary jointed beds. The rocks in the bed of the creek are exposed in very broad tables, the one where the disturbance occurred being over two hundred feet long and perhaps twenty feet wide. Above and below this point, the stream had slight falls over the edges of similar beds. Just at this point its bed was upon this broad sheet of rock, all of one layer. The disturbance, which was very conspicuous, consisted in a low ridge, about three feet wide and about ten inches high in the middle, which extended obliquely across the stream for a distance of one hundred and fifty feet, either end disappearing beneath the bank of alluvium that bordered the stream. The top of the ridge was shattered into fragments by the process of upheaval, spalls of rock to the number of hundreds having been thrown from its surface by the movement. The top of the ridge was seamed by a fissure about half an inch wide, which was irregular in its direction and width.

Fortunately, the formation of this curious ridge was intelligently observed by the son of Mr. Cornelius Trailor, on whose farm the disturbance occurred. At early day, coming with a horse to a watering-place near the stream, he heard the roaring sound beneath the earth, which was so violent as to cause his horse to break away from him. In a moment he saw the stones begin to fly from the rock in the bed of the creek, near the bank, and directly saw that the disturbance advanced up stream. Following the movement, which went on at the rate of a slow walk, he saw it finally disappear beneath the opposite bank. During the rest of the day there were frequent sounds as of further rending of the rocks at depths beneath the upheaved surface; but by nightfall the sounds had all ceased, and had not been renewed up to the time of my inspection.

The general course of this small ridge was northeast and southwest, agreeing with the trend of the greater mountain ridges to the eastward; but this coincidence may well have been accidental. I shall endeavor to discuss the origin of this peculiar accident in the Memoirs of the Survey. I may say, however, that it is evident that there is in the beds beneath these rocks some force that tends to push them into a smaller compass. The origin of this contractile force is as yet unexplained. I am inclined to seek it in the gradual removal from the underlying limestones of quantities of various soluble salts, through the action of our spring waters. In this way a great contraction of their mass is brought about, which may be represented to the reader by the familiar example of drying wood or the shrinkage of brick clay in burning. The escape of matter, in any of these cases, brings about a very violent contraction of the mass. These lower-lying beds, seeking, with great energy, to contract, the superior beds are put upon a strain tending to throw them into folds, such as we have been considering.

The scientific interest in this class of phenomena is great, inasmuch as they serve to show that our Kentucky rocks, though the least disturbed of any of their age, are the seat

of changes which may bring about continued slight disturbances of equilibrium, though they may not cause any far-reaching results.

I have now given, as briefly as possible, an account of the most important conclusions that have been obtained during the past two years of work of the Survey. There are many other less well-observed matters, which must remain among the unfinished work for some time to come, of which it is not worth while to give even the most general account. All the matters I have treated of will, in due time, be found in more completed shape in the several publications of the Survey. If the general index now in preparation is carried on to completion, the reader will find therein full references to all the work done by the Survey upon the several matters touched upon in this Report.

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GEOLOGICAL SURVEY OF KENTUCKY.

N. S. SHALER, DIRECTOR.

REPORT ON THE UNFINISHED WORK

OF THE

SURVEY OF THE COMMONWEALTH

UNDER THE

DIRECTION OF DR. DAVID DALE OWEN,

BY N. S. SHALER.

PART VIII. VOL. III. SECOND SERIES.

STEREOTYPED FOR THE SURVEY BY MAJOR, JOHNSTON & BARRETT, YEOMAN PRESS, FRANKFORT, KY.

415 & 416

REPORT ON THE UNFINISHED WORK OF THE SURVEY OF THE COMMONWEALTH, UNDER THE DIRECTION OF DR. DAVID DALE OWEN.

In reconstituting the Geological Survey of Kentucky, the Legislature very properly provided that the new work should be made a continuation of that which had been begun under the direction of Dr. Owen. In pursuance of this command, a careful search has been made for all the material left unpublished by the sudden stoppage of the work in 1860. The death of Dr. Owen in that year, the ravages of the civil war, and various accidents, such as the burning of certain records in the offices of the Commonwealth at Frankfort, has left little to be gathered together. Some few topographical notes have been embodied in the maps given in the first, second, fourth, and fifth volumes of the new series. Some collections of soils made by Dr. Owen's assistants have been analyzed by Dr. Peter, and the results given in his reports.

I present herewith the only two considerable works that have come to me in the records of the old Survey. The first of these, the geological section along the east and west base line of the Survey, made by Sidney S. Lyon, Assistant of the Survey, is all that has been found in the way of records of that arduous work. I have elsewhere expressed the opinion that the labor given to this task was, to a great extent, misplaced, as it was not possible to make a satisfactory map of the State in the way designed by Dr. Owen. The topography planned by him was essentially based on the methods of the only surveys with which he was personally familiar—those made by the General Government in laying out the lands of the new Territories. This method has been unanimously condemned by all cartographers as wanting in those corrections which experience has shown can alone be given by the ac-

curate system of triangulation which is used in all our best modern government surveys. The extension of the triangulation work of the Coast Survey to the interior of the United States, in a way that furnishes a thorough geodetic foundation for the topographical work of any State survey, takes away the need of the class of work which Dr. Owen sought to do in this imperfect fashion. I have, therefore, not thought it worth while to try to recover the bench and distance marks of his base line—a task which, owing to the imperfect method of designation, would be now, after the expiration of twenty years, very hard to accomplish.

The section with the sketch of the topography, which is given in the first plate in this Report, has a certain value, independent of the aim that led to its making. It will be seen that it gives, in considerable detail, a generalized geological section across the Cincinnati, or, as I would prefer to call it, the Ohio axis, which is the key to the structural geology of Kentucky. Although the work seems rudely done, when measured by the advanced standards of our modern geology, it is, in a certain way, an advance on anything that had been done at the time when it was executed. The great disproportion between the horizontal and vertical scales of the section is a defect common to all the work of its day, and it occurs in most of our more modern sections as well. The result is a very much distorted idea of the steepness of all declivities, whether of the surface of the ground or of the slopes of the various strata. The reader should be warned that the eastern part of the section, which seems as rugged as the sky line of the rudest mountains, in fact represents a region of rather gentle slopes, through which railways could be built at scarcely more cost than in the more level central parts of the section. He should also notice that the various separate groups of rocks are but imperfectly given, not half the well marked divisions being taken into account in this diagram.

In making these criticisms upon the work of my distinguished and lamented predecessor, I would not be suspected

of a disposition to disparage his eminent services to the geology of our Commonwealth, as well as to American geology in general. Each step in reviewing his labors confirms me in the opinion that he was a man of great genius and of the most constant fidelity to his work. The only limitations to the goodness of his work were brought about by the slender means at his command, and the necessary restriction of all his labors to reconnoissance surveys, in which branch of geological surveying he deserves the very highest rank.

The third plate given in this Report contains an important piece of topographical work, by Joseph Lesley, Esq., Topographical Assistant with Dr. Owen, now Secretary of the Pennsylvania Railway. This work, like that of Lyon, was designed to serve the purpose of a base line on which to build the topography of the State. It will be seen that the measurements extend from near the Ohio river to the Tennessee border, and that they essentially coincide with the western outcrop of the eastern or Appalachian coal field.

As a piece of topographical work, this base-line Survey of Mr. Lesley's has, I believe, never been surpassed in the western country. Unfortunately, the original map, in twenty large sheets, on the scale of one ten thousandth, was loaned by the State Government to the officers of U. S. engineers during the civil war. The data it afforded were roughly embodied in the so-called military map of the Commonwealth, which was prepared in 1863–'5, but which, owing to the loss of the lithographic plates in the burning of Pike's Opera House, in Cincinnati, was never published, a few copies only being now in existence. The original sheets of Mr. Lesley's work have been anxiously sought for in the Government archives—the officers of the War Department and the U. S. engineers having given me all possible aid in my efforts to recover these records. Fortunately, Mr. Lesley had made a full reduction of his maps to the scale given in this section, which will serve to preserve the most valuable features of his admirable work.

The sketch map which accompanies this Report was designed to give the western outcrop of the eastern coal field

in a convenient form, in anticipation of the completion of the topographic work in this section, without which a detailed showing would not be possible. This sketch has already been embodied in the general geological map of the State. It is reproduced here in justice to the work of Mr. Lesley, and in order to show just what work had been done during the direction of Dr. Owen.

In the work of Mr. Lesley, as in that of Dr. Owen, the greater part of the usefulness of the base lines measured has been lost, owing to the change of plan arising from the substitution of triangulation for the method of base lines used by Dr. Owen; but Mr. Lesley's work, unlike that of Mr. Lyon, has a direct value for the amount and accuracy of topographical work done along the base line, and the excelling hypsometric determinations made in connection therewith. Wherever this work of Mr. Lesley's has been reviewed, in the advance of the present Survey, it has been found of the most satisfactory character.

It should be said, in explanation of the delay in bringing out these fragments of Dr. Owen's work, that it was long after the re-institution of the Survey before the materials came into my hands, and only within a few months of the present time that I have been forced to give up all hope of getting access to other original records of the same nature.

THE OUTCROP BELT OF THE EAST KENTUCKY COAL FIELD.

To accompany a Map originally presented to the American Philosophical Society, June 20th, 1873. By Joseph Lesley, Late Assistant on the Kentucky Geological Survey.

Under appointment of David Dale Owen, State Geologist of Kentucky, I began, on the 25th of August, 1858, a geological and topographical survey of the margin of the eastern coal field of the State, to determine its area, and the number, thickness, and attitude of its beds of coal and iron ore, and to get a reliable base for a future survey of the whole eastern coal field as far as to the Virginia line.

The base line of my survey was run upon the common roads of the country—flying side lines, and, in some cases, closed looped lines, being carried out sideways to the western outcrops wherever necessary.

An admirably constructed odometer was used for measuring distances, and a compass with side-telescope and eccentric target for running courses. Aneroid observations, regularly taken at every station, were checked by clinometric measurements made with a vertical circle attached to the telescope, and also by synchronous observations with a barometer stationary in camp.

The main base line was also carefully leveled, for a distance of about two hundred miles, with a spirit-level, which was also used on some of the side lines, in order to tie the parts of the work together, and to give the exact datum above tide-water for all principal stations, in view of adopting them as starting points of the contemplated survey of the whole coal field.

The work thus described was continued from September 1, 1858, to November 1, 1859, seven months being passed in field work, and with the following results:

1st. A large contour-line map was made on a scale of three miles to the inch, which has never been published. The original plottings were on a scale of five hundred feet to the inch.* This map includes only the ground covered by the survey, and shows the positions of towns, county line crossings, coal openings, and other points of interest, as well as the crossing of the long east and west base line run by S. S. Lyon, Assistant on the State Geological Survey.

2d. The map, now published for the first time, to accompany this description, was compiled from the survey sheets of the first named map, from old maps in the Internal Improvement Office, from railway surveys, and from the old State map.

3d. A base line for future use, extending in a general southwest direction along the strike of the formations, beginning at a point five hundred and ninety-seven feet above tide, close by the town of Grayson, in Carter county, Northeast Kentucky, and extending, by a loop embracing a section covered by the Little Sandy river and its tributaries, to the ridge dividing Carter from Rowan counties; thence across the east end of Bath county to Jeffersonville, in Montgomery county; thence to the Red River Iron-works, on the edge of Estill county; thence to the town of Proctor and its coal mines, on the Kentucky river; thence across Owsley county to McKee, in Jackson county; thence to Mt. Vernon, in Rockcastle county, and Somerset, in Pulaski county; thence across the Cumberland river, at the "lower ford," to Monticello, in Wayne county; and thence to its southern terminus on the Tennessee State line, in Clinton county, at a point on the waters of Wolf river, one thousand and nineteen feet above tide.

4th. The establishment of sixty-two bench marks, showing elevation above tide and above low water in the Ohio river at Catlettsburg.

5th. An unpublished geological section to accompany Map No. 1.

*These maps were loaned to the U. S. engineers by the Government of the Commonwealth during the late civil war. The most careful search for them has been unsuccessful. Through the kindness of General Humphreys, the records of the engineer corps at Washington have been ransacked in this fruitless search. N. S. S.

By observations made during the progress of the work, the following points of scientific interest present themselves:

1st. In approaching this coal field from Middle Kentucky, over the lower Silurian formations, one is confronted by a belt of cone-shaped hills, having the Devonian black slates in their gently sloping bases, upon which rise steeper slopes of the olive-colored shales and overlying grit stones of the same system. These shales and grit stones, together, vary in thickness from three hundred and fifty to five hundred and fifty feet, the lower and larger division of the formation having disseminated through it nodular masses of earthy iron ore, giving origin to numerous chalybeate springs, the upper division affording valuable building stone.

Upon the above named rocks lies the Mountain or Sub-carboniferous limestone, varying in thickness from seventy feet, at the north end of the line, to four hundred feet and more at the southern end. This formation is composed of alternating layers of white, grey, and buff-colored strata, ranging in quality from argillaceous claystone to the purest plaster limestone. The lowest members of the series hold large dark green flint pebbles, and exhibit traces of galena. Dry valleys and numerous caves distinguish this formation.

Above these limestones lies the millstone grit formation (the Conglomerate No. XII of the Pennsylvania Survey), in two members, the lower made up of thin sandstones and shales, inclosing beds of coal and iron ore. This is named the "Sub-conglomerate" member. The upper or "Conglomerate" proper consists of a massive, coarse-grained ferruginous sand-rock containing pebbles.

The two members of this formation thicken southwestwardly, as do also the rocks of the previously mentioned formations, on which they repose, but under different and peculiar conditions.

At Grayson the whole formation measures ninety feet, with the "lowest" coal bed—a mere streak—jammed between its base and the top of the limestone.

At the north fork of Licking river the upper member is one hundred and fifty feet thick; while the lower one is only eight feet thick, and contains a well-defined bed of iron ore and a twelve-inch coal bed.

In Estill county the upper member measures two hundred feet; the lower has also increased to fifty feet, its accompanying ore bed being now workable, and its coal bed measuring twenty-seven inches in thickness.

From this last named point to the south end of the line at the Tennessee State line the peculiar character of this formation shows itself in a marked manner, its lower member increasing to an average thickness of two hundred and twenty-five feet, and containing two workable and three other thin beds of coal, and three well-defined horizons of shale containing iron ore, its upper member nowhere exceeding eighty feet in thickness.

The point of sudden change lies geographically between the top of the ridge dividing the Red and Kentucky rivers and the valley of the Kentucky river itself.

The "lowest" coal bed holds its place throughout the belt, the other Sub-conglomerate coals mentioned above coming in, one by one, above it, and in proportion to the constant thickening of the lower member of the formation.

Back from the greatly eroded and boldly rising wall of the Conglomerate, which always marks the western margin of the East Kentucky coal field, lie, thinly spread over a plateau trenched by ravines, the lowest layers of the lower coal measures proper.

2d. All the formations mentioned above dip to the southeast, making the western side of a wide and shallow synclinal trough.

3d. This great wave, having its axis in a direction north northeast and south southwest, is itself crossed by undulations of no great height and depth, having their axes west northwest and east southeast. Gentle as those undulations were, they were quite sufficient to determine the principal

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lines of drainage which issue from the mountain country into the plain.

4th. All the formations examined along the base line thicken, and also rise above sea level, going towards the southwest.

5th. The lowest Sub-conglomerate coal varies in thickness, but is persistent throughout the whole extent of the belt surveyed, a distance of about two hundred miles.

6th. Different species of trees mark the outcrops of the different geological formations. The sugar-tree and other maples, and the white oak, are characteristic of the base of the Devonian "knobstone" series. Beech and red cedar grow on the Sub-carboniferous limestones. Pine, hemlock, laurel, and holly possess the Conglomerate cliffs and peaks. Chestnut and oak forests cover the shales and sandstones of the great plateau bordered by the Conglomerate bluffs.

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