GEOLOGICAL SURVEY OF KENTUCKY.

N. S. SHALER, Director.

REPORTS OF PROGRESS.

VOLUME V. NEW SERIES.

STEREOTYPED FOR THE SURVEY
BY MAJOR, JOHNSTON & BARRETT.
YEOMAN PRESS, FRANKFORT, KENTUCKY.
1880.

INTRODUCTION.

This, the fifth volume of economic reports of the second Geological Survey of Kentucky, contains matter concerning the researches of the Survey which has been published in the form of detached reports from the years 1878 to 1880, inclusive. This volume, together with the Bulletin of the Survey, of which several numbers have been issued, contain all the statements of economic importance concerning the field explorations that have been conducted during these years, as far as they can yet be made sufficiently certain to warrant their publication. The more general scientific results of the Survey will be found in the second volume of Memoirs, which is now going through the press. A great deal of the work done by the parties and individual workers of the Survey will necessarily remain unpublished until the final reports are prepared.

The first of the reports in this volume accompanies the map of the reconnoissance triangulation prepared by Assistant W. B. Page, who, for some years, carried on the geodetic work undertaken by the United States Coast Survey. This work is designed to furnish the basis for the final map of the Commonwealth, and will make it possible to frame this map on a much more accurate basis than could otherwise be secured. If this system is carried out, as we may hope it will be, the topographical work done by the Geological Survey will be final in its nature, and will not require the subsequent repetition which is inseparable from map work done without a system of triangulation of the most exact kind. It is to be regretted that Mr. Page has resigned his connection with the Survey and sought employment in other and more profitable fields. The Commonwealth has never had a more faithful or efficient servant. The larger part of his work is embodied in the published and unpublished maps prepared in his work as a topographer of the Survey; but in the several topographical reports that accompany these published maps, he has given the best descriptions of surface characters that have yet been furnished for any of the Southern States. The further prosecution of this work has been intrusted to Assistant Schenk, who brings to his task a skill and diligence that has been marked in all of his numerous labors in connection with this Survey.

The second report of this series gives a record of Mr. Schenk's labor in the extension of the topography of the eastern district during the year 1874. A part of this work will necessarily remain for the present unpublished. As it has been found too expensive to prepare contour maps to illustrate the topography of the State, descriptions of the surface, such as are given by Mr. Schenk, have a decided value to the persons who desire a more detailed statement concerning its surface than the plain maps themselves will give. This seems to me a warrant for reports of this nature.

The third report is also from the pen of Mr. Schenk. It concerns the use of the telemeter or topographical maps. At the outset of the present Geological Survey I determined to substitute for the surveyor's chain the telemeter, the special advantages of which had been made plain to me during my experience as an employé of the United States Coast Survey. I knew of no simple and accessible essay on the use of this instrument, and as the methods to be followed in making surveys with it are not generally familiar to our surveyors, who rarely know much of this instrument, it seemed desirable to have some treatise on the subject from the hands of a master in its use. I believe Mr. Schenk's paper will serve this purpose, and I hope it may contribute to the more extended use of an instrument that may fairly be regarded as the greatest modern contribution to the surveyor's art. I am not aware that the telemeter has been much used in any other field for the work of rapid map-making. Our experience with it in Kentucky has shown that facility in its use is speedily acquired, and that the results are as accurate and far less costly than those attained by the old methods.

The fourth report is from Assistant DeFriese. It contains a valuable account of the economic timbers in the valley of the Tradewater river. Besides the information of industrial value, his account of the distribution and succession of the various forest trees, adds another chapter to the important general results that have been attained by the Survey. It is of great importance that these matters connected with the history of our forests should be ascertained as rapidly as possible. Already their original character is well nigh lost by the changes that the axe brings about.

The fifth report in this volume contains another of the series of memoirs on the nature and distribution of the timber trees of Kentucky, by Mr. L. H. DeFriese. Besides No. 4 of this volume, Mr. DeFriese has already contributed several reports on this class of subjects to the preceding volumes of this series—the whole constituting an extended and valuable synopsis of his studies upon this class of questions. Besides the large amount of special economic information this report contains, it includes a brief discussion of some problems of general interest to all who are interested in the present history of our forests. As I have remarked in previous discussions of these questions, the forests of this Commonwealth afford the best possible field for certain inquiries. The problems presented by our prairies have great light thrown upon them by the facts that can be gathered here. Mr. DeFriese has clearly shown in this report that the extension of the treeless areas was in some cases due to the burning of the grass by the early settlers, a process that was adopted from the aborigines, and which served to destroy the younger trees, and so in time to give prairie surfaces to wide regions that were previously wooded. The observations in this report have a special interest, inasmuch as they show the continuance of this work of extending the prairie limits down to a very recent day. I regret that it seems at present unlikely that the Survey will be able to secure any further studies of this description from Mr. DeFriese. It would be very desirable to have this class of observations extended over the whole surface of the Commonwealth. I trust, however, that the important features adopted in these timber reports given us by Mr. DeFriese, and the other officers of the Survey who have taken part in these forest studies, may be secured in the reports of those who continue the work on the lines laid down by the published reports. In this way we should secure a study of our forests more complete and valuable than has been made in any other area of its size in this country.

In the Chemical Report, the sixth of this volume, we have the third of the valuable contributions that Dr. Peter has made to the new series of the Survey, and the seventh since the beginning of the study of the resources of the Commonwealth; four other reports having been published during the years in which Dr. Owen had charge of this department.

In this report Dr. Peter continues his studies in the composition of our coals, soils, clays, &c., &c. These analyses are accompanied by various comments serving to show their relation to previous work or the economic results that may be derived from them. Those concerning the soils are a continuation of the many hundred previously made by Dr. Peter and published in former reports. This series of analyses now affords a nearly complete basis on which to construct a soil map of the Commonwealth, which shall show the distribution of its various soils, the crops for which they are severally fitted, and the fertilizers that can be most advantageously employed upon them. The work done upon the mineral waters nearly completes the examination of our medicinal springs. There now only remains about half a dozen of the mineral waters of this State that have not received some study from the Survey. In this connection it is worthy of note that some of our underground waters, such as are found by borings in the limestone beneath the Blue Grass district, are shown by Dr. Peter to be fit for steam purposes. As we must abandon all hope of procuring waters for the supply of our towns by means of artesian wells, it is a great satisfac-

tion to know that we may, under some circumstances, find them fit for use in steam boilers.

The analyses of the Hungarian grass and German millet are valuable contributions to the economic chemistry of two of the most useful forage plants. The high price of lands in the central district of Kentucky makes it desirable for us to use the forage plants of the largest yield. The relation of these plants to our soils is therefore a matter of great interest.

In preceding reports Dr. Peter has given similar studies upon the greater part of our important agricultural products. When the final reports of the Geological Survey come to be prepared, it will be desirable to have these general reports on the chemical survey of the Commonwealth worked over, so as to bring the related matters together. At present a large part of their important contents is so scattered as not to be available to the student. Four of these reports are in the old series of publications, which have long been out of print, and are mostly inaccessible to our people.

The report of Assistant Caldwell on the iron ores of the Cumberland district is the third of his memoirs on the iron resources of Eastern Kentucky. These, with the reports of Mr. P. N. Moore, who preceded Mr. Caldwell as metallurgical assistant of the Survey, give a reasonably full account of the prospects of this industry in Kentucky. To a large training in the metallurgical schools of Europe, Mr. Caldwell has added an extensive experience in the practice of working iron in this country; so his results are worthy of the fullest confidence.

I deem it of particular importance that Mr. Caldwell considers the iron ores of the Cumberland district as fit for steel-making purposes. There are very few ores of this class in the valley of the Mississippi, and at no other point are they found in such close juxtaposition with fuel of a cheap sort. Although the United States abounds in iron ores, the greater part of its resources of this nature are not conveniently placed with reference to transportation, and are rather remote from cheap coal. It is a peculiar advantage of our Kentucky ores, which those of Northern Kentucky prove in an eminent degree, that they are all near to good coking coals and not remote from water transportation. The ores of the Green River district and of the Cumberland and Tennessee districts are easily accessible by rail or water transportation.

The next report in this volume is also from the pen of Mr. Caldwell. It is intended as a summary of the modern advances in the metallurgy of iron. Many of the important discoveries in this art are inaccessible to its practical workers. No modern art has profited more by intelligent experiment conducted with scientific methods than this. It has seemed to me well to recognize the fact that this Survey was intended to diffuse such knowledge among our people. So far as my knowledge goes, this is the best brief presentation of the matter that has yet been given to the public.

The remarks in this report concerning the modern advances in the removal of phosphorus from iron are of especial importance to our Kentucky iron interests, as a large part of our iron ores are rather phosphatic, and it has hitherto been announced that they were unfit for the making of steel, which is now so extensively taking the place of ordinary iron. It seems clear, however, that we may now disregard this impurity, for the most recent advances in the process of manufacture show us means of effecting its removal at an inconsiderable expense.

The tenth report in this volume is from the pen of Mr. L. H. DeFriese, who has written two other reports in this volume. The special aim of this report was to furnish a continuous section across the State from east to west, showing the changes of the trees in passing from the banks of the Mississippi to the mountain district along the Virginia border of the Commonwealth. Besides the practical details introduced in his report, there are several suggestions of great theoretical interest. As before remarked, the forests of Kentucky abound in problems. The order of succession of the various trees, the laws that determine their appearance and disappearance in the various districts, the curious way in which certain species, unhappily including the precious white oak, are fading out from the want of young trees in the undergrowth, are all matters of great scientific as well as economic importance. Mr. DeFriese has laid the foundations for very important inquiries into many of these matters, and in some cases he has been able to make important conclusions concerning them.

The report of Mr. W. M. Linney stands in natural relation to that of Mr. DeFriese. It is, in fact, a detailed study of the district comprised within the counties of Boyle and Mercer, which has been touched upon in the last report of Mr. DeFriese. Mr. Linney, during a long residence in this district, has paid especial attention to the history of its once well-wooded lands. He tells a painful story of the successive advances in the destruction of the noble forests that have had to give way before the highly developed agriculture that its admirable soil invites. I know of no other region of equal extent, in this country or Europe, where the land is so completely deprived of its natural forests as this central district of Kentucky. In the central parts of England, the most thickly settled portion of that over-peopled isle, there are here and there considerable tracts of forest, which, with their undergrowth and spongy bed of decaying vegetation, serve to restrain the movement of the rain-water towards the streams. But the value of grazing lands in Central Kentucky is so great that all the woods are deprived of their undergrowth, and set with a close sod, so that the water goes off its surface with almost the same ease that it flows from the roofs and streets of a city. There are two very regretable results arising from this utter neglect of the forests in this district—first, the destruction of the streams, which are no longer as of old constant channels of water, but torrents in the seasons of rain and dry ways in the times of drought; and second, the gradual destruction of the value of the pasture lands of the district from the action of drought and the want of shade. It is a well recognized fact that the high bred and sensitive animals of our breeding farms are considerably affected by the heat of the summer sun. It is because they afford shade to animals while they are feeding that the wood pastures of our blue grass country are peculiarly prized by stock-growers. At present no provision is made for the renewal of the trees of these wood pastures. They are generally waxing old, and a few more decades will bring about their destruction. Although we cannot expect to see any great part of these lands replanted in forests, we may at least hope that this special need may receive immediate attention.

The twelfth report on this series is from Professor A. R. Crandall, of the State Agricultural School, on the Chinn's Branch Cannel Coal District. There are only two considerable areas of cannel coal near to the line of the Ohio river within the Commonwealth—this, which is the subject of Mr. Crandall's report, and that known as the Breckinridge Cannel Coal in Hancock county. Although there are large areas of this peculiar variety of coal in the region adjacent to the head waters of the Licking and Kentucky rivers, these coals along the Ohio will always have a certain advantage from their proximity to water navigation. In the large markets of the West they always have a value of at least one dollar a ton above the ordinary bituminous varieties, on account of their peculiar fitness for the production of gas and their suitability for domestic uses. These coals lie in a very favorable position for production, and invite the attention of capitalists more than almost any other of our resources. There can never be much competition with the products of these basins, for the other localities must convey their coals over routes of greater length and cost.

The last report in this volume is from Dr. Robert Peter, chemist of the Survey.

This report is introduced by some interesting general statements concerning the soils of Kentucky, of which specimens from seven hundred and seventy-two localities have been subjected to analysis. It appears from this account that there are twenty-nine counties not represented in these studies, and the work is, as a whole, rather irregularly distrib-

uted, though it represents the most important agricultural regions of the State with tolerable completeness. This brief synopsis shows us clearly how important it is to have this disconnected information brought into the compass of a single volume, and so displayed as to make its teachings have their full value.

Following this matter is a brief discussion of the chemical history of hydraulic cements. The lower lying formations of the Commonwealth abound in rocks fitted for use as hydraulic cements, and as the use of this substance is constantly increasing, a special report on the matter should soon be prepared. In this research the chemical study should take the first place. The inquiry may demand several hundred careful analyses, but its results will justify at least a year of labor by Dr. Peter and his assistant.

This report also gives the results of several analyses of marly clays from the so-called lower Silurian limestone series of rocks. These deposits sometimes show very considerable amounts of potash, and if found of sufficient thickness may prove valuable for fertilizing purposes, especially upon tobacco lands. So far the study of the marls and other fertilizers of the State has only been made in the way of reconnoissance. It was best that the institution of a plan for this inquiry should be left until the chance work of the Survey should show the general direction in which it should be turned. It now seems clear that every bed of shale in our rocks, from the lowest part of the section to the top of the Subcarboniferous, should be subjected to a searching inquiry, to show the amounts of potash, soda, and phosphates they may contain. In this way I feel sure that we shall find out some valuable resources which will aid us in preserving and increasing the fertility of our soils.

A good part of the soil analyses given in this report of Dr. Peter was made upon specimens collected during the Survey of Dr. D. D. Owen, by Mr. Joseph Lesley, jr., to whom we are indebted for much of the valuable work done during that

Survey. These samples have long awaited the time when the pressure of other work would permit their study.

A word of personal explanation is now due to the reader. The pressure of other engagements has made it necessary for me to resign my position as Director of the Survey of the Commonwealth. For some years the necessity of this action had been apparent, and was only delayed in order that I might feel sure that the succession would fall into the hands of one well qualified to continue the work to its completion. I now feel sure that all the incomplete work of the Survey will be in better charge than I could give to it. By the kindness of my successor I have been permitted to retain charge of the unpublished work done during my incumbency. Of this there yet remains the sixth volume of Reports, the second of Memoirs, one or two volumes of photographs with text, and the general index to one volume, which is to give the key to all the work reported in the first and second series of reports and in the other publications of the Survey. This index volume is nearly ready for the press, awaiting only the completion of the sixth volume of Reports and the second of Memoirs.

As this introduction leaves my hands I learn of the sudden death of Mr. W. B. Caldwell, jr., long metallurgical assistant of the Survey. I cannot forbear to note my sense of the magnitude of this loss to our people. Every circumstance seemed to lend itself to make a bright future for this young man. Excellent capabilities, well developed by a thorough training in his chosen work, a charming person, an eagerness and joy in the activities of the world which the certainty of a great inheritance seemed not to dampen, helped to make his friends hopeful that his career was to be full of happiness and honor. I looked to him for the prosecution of many researches that we had often discussed together.

N. S. SHALER.

OFFICERS OF KENTUCKY GEOLOGICAL SURVEY

DURING THE TIME OF PREPARATION OF THE REPORTS CONTAINED IN THIS VOLUME, IN THE ORDER OF THEIR APPOINTMENTS.

NATHANIEL SOUTHGATE SHALER, *Director and Principal Geologist.*
ROBERT PETER, *Principal Chemist.*
ALBERT ROGERS CRANDALL, *First Assistant in Geology.*
PHILIP NORTH MOORE, *Assistant in Geology.*
CHARLES SCHENK, *Assistant in Topography.*
CHARLES JOSEPH NORWOOD, *Assistant in Geology.*
WILLIAM BYRD PAGE, *First Assistant in Topography.*
LUCIAN CARR, *Assistant in Ethnology.*
JOHN HOLLIDAY TALBUTT, *Assistant in Chemistry.*
JOHN ROBERT PROCTER, *Assistant in Geology.*
CHARLES WICKLIFFE BECKHAM, *Assistant in Topography.*
EUGENE UNDERWOOD, JR., *Assistant in Topography.*
JOSEPH BERNARD HOEING, *Assistant in Topography.*
LAFAYETTE HOYT DEFRIESE, *Assistant in Botany.*
WILLIAM B. CALDWELL, JR., *Assistant in Mineralogy.*
WILLIAM M. LINNEY, *Assistant in Geology.*

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VOLUME V.

GEOLOGICAL SURVEY OF KENTUCKY.

N. S. SHALER, DIRECTOR.

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.

PART I. VOL. V. SECOND SERIES.

STEREOTYPED FOR THE SURVEY BY MAJOR, JOHNSTON & BARRETT, YEOMAN PRESS, FRANKFORT, KY.

INTRODUCTORY LETTER.

OFFICE KENTUCKY GEOLOGICAL SURVEY,
FRANKFORT, KY., March 1st, 1877.

Professor N. S. SHALER, *Director Kentucky Geological Survey:*

DEAR SIR: Herewith submitted you will find a description of the topography of the area included within the reconnoissance triangulation of the United States Coast Survey in the State during the seasons of 1875 and 1876.

The subject is treated with reference to its importance in connection with the topographical work of the Geological Survey. The sketch accompanying the report was drawn by Mr. Joseph B. Hoeing, who aided in the original reconnoissance last season.

The sketch shows the result of the reconnoissance, barometric heights, the topography with reference to the stations, the proposed base lines and connections, and the principal stations on the scale of the preliminary map of the State.

Very respectfully,

WM. BYRD PAGE.

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.

The reconnoissance triangulation for the United States Geodetic Survey in Kentucky, under the direction of the United States Coast Survey, has been prosecuted during the working seasons of 1875 and 1876. The general instructions in this work were to commence in the southeastern portion of the State, and to proceed in a northwest direction toward the Ohio river; to establish such primary stations as would be found suitable, and such intermediate or secondary stations as would aid in the determination and delineation of the topography; to ascertain the relative heights of stations, and to make such other observations as would assist in the work of the Geological Survey.

The sketch of the reconnoissance is not to be considered as a determined and approved scheme, but rather as the result of the preliminary work performed, from which a scheme may be selected for final triangulation.

It is from work of this character that the State must obtain an accurate basis for a final and complete topographical map. The detailed surveys of portions of the State already completed, and those now progressing under the direction of the Geological Survey, although complete and accurate within their limits, will be dependent for their proper relative positions upon the triangulation, and it is with this view the topography is carried forward.

From the above considerations the results of the reconnoissance may be of interest to the citizens of the Commonwealth. The topographical features of the area included in this reconnoissance will be discussed with especial reference to the size and general location of the quadrilaterals and triangles of the scheme.

The area of the work is wholly within the water-shed or valley of the Ohio river. Commencing at the Cumberland Mountains near Cumberland Gap, where is the intersection of the boundary lines of the States of Kentucky, Virginia, and Tennessee, the direction of the work was toward the Ohio river, across the State at right angles to the greatest length. In the direction of that river a continued contraction in the order of triangulation was to be expected. The order, or size, of the triangulation will vary most in this direction. The schemes of the same order will probably extend northeasterly and southwesterly, the topographical features in these directions being more nearly alike.

The possibilities for extensions in other directions were ascertained as thoroughly as practicable as the reconnoissance progressed toward the Ohio river. From the eastern limit of the work, the Cumberland Mountains, the outlook to the eastward and southeastward was very distant, extending far toward the summits of the Appalachian range. When the atmosphere was sufficiently clear distant peaks, probably the Smoky or Unaka Mountains of North Carolina, were observed.

The feasibility of extension in either the northwest or southeast directions is at least equal to that in the direction pursued. To the west the outlook is certainly favorable. The sketch includes about two thirds of the distance from the State line to the Ohio river. The first quadrilateral includes about thirty miles of the Cumberland Mountains; the direction of the chain is about northeast and southwest. The range, being a folded or uplifted mountain, has a decided crest, and is without spurs of size. Five points on the range have been located, and are shown on the sketch. Cumberland Gap is the lowest point in this length of the range; its height above sea-level is one thousand six hundred and

seventy-five feet. The height of the mountain varies from one thousand to two thousand feet above the valley on the Virginia and Tennessee side. The valley of Yellow creek, on the Kentucky side, is one hundred and sixty feet lower than the valley on the Tennessee side. The heights of the several points are given on the sketch. The "White Rocks" station is the highest point included within the scheme or yet measured in the State. Powell's river, on the east side of the mountain, is parallel to it, forming an open valley of considerable width.

On the Kentucky side are numerous small streams, the head waters of the Cumberland river draining from the mountain to the northwest. Between these streams and their branches are the Brush and Log mountains, both intricate in construction, and in height equal to or greater than the Cumberland, which lies opposite them.

They limit the horizon of the Cumberland to the northwest at many points. The Brush Mountains attain a height of three thousand two hundred feet, are level for several miles, and form their junction with the Cumberland Mountain with but little drop in height. West from the "White Rocks" their height has diminished, and they do not intercept any view in that direction. The Log Mountains have many and irregular spurs extending in all directions; they extend between the Cumberland and Pine Mountains, and about double this length in a transverse direction. These mountains are limited on the east and west by Yellow creek and Clear Fork. The peaks are of various heights. The summit known as "Bryson" attains a height of three thousand two hundred feet. This point overlooks the Cumberland Mountains to the eastward, and from it the mountains of North Carolina were observed. The view to the westward is limited by a range of the same mountains, distant about five miles. For this reason this point was not found available as a primary station of the proposed scheme.

To the northward of this point, in the vicinity of Canada Mountain, the overlook into Kentucky, from the north to the west, is very extensive. These mountains as a range, no known peak being distinguishable, were observed from Green River Knob, distant nearly seventy miles. Parallel to, and about ten miles distant from, the Cumberland range, is the Pine Mountain. Unlike the Cumberland, it is a fault mountain; it is straight and even in height. The position of one point of the range just above Pineville was determined.*

At this point is the water-gap through which the Cumberland river, draining the area above referred to, passes to the northwestern side of the range.

From this point the river makes a decided bend to the northward and westward, and thence somewhat toward the Pine Mountain again. Between the river and Pine Mountain are the Brush Creek hills, resembling in topographical features the Log Mountains. At a few of the summits these hills nearly equal the Pine Mountains in height.

To the north of the Cumberland river to "Paint Gap" Station, on the divide between the Cumberland and Kentucky, are innumerable peaks similar in shape and about equal in height. This rendered it impossible to recognize or locate intermediate points without more detailed work. The area described is included within the first quadrilateral of the proposed scheme. Its area is about seven hundred square miles, and the heights have fallen from three thousand four hundred and sixty and two thousand nine hundred and five feet on the Cumberland Mountain, to two thousand and forty and one thousand eight hundred and sixty feet at the stations "Paint Gap" and "King Knob." King Knob is the summit of a considerable area, the drainage flowing in nearly every direction to the Cumberland river. Raccoon Mountain is the next point reached; it is the summit from which flow the Laurel rivers, Rockcastle, and Raccoon creek, one of its branches. This area is drained principally by the Laurel rivers, and is nearly altogether within the drainage of the Cumberland

*A fuller account of the structure and topography of this region will be found in the third volume of these reports, 1877, and also in the Memoirs of the Survey. In the American Naturalist for July, 1877, there will be found a diagram and description which will convey a more extended idea of the geology and geography of this district.

river. The line from "Paint Gap" to "Raccoon" has about the direction of the ridge dividing the Cumberland and Kentucky rivers. The features of the country have changed decidedly; the general surface has become much more level, the heights of Raccoon only appearing on the divides. Much of this area will average the height of London, Laurel county, one thousand one hundred and sixty feet, which is about three hundred and fifty feet above Rockcastle river, at Livingston. The sandstones of the coal measures are the surface rocks determining the character of this area.

The quadrilateral—King Knob, Raccoon, Brushy, Green River Knob—together with the triangle to Bear Knob, include within their area the width of the northern water-shed of the Cumberland river; the line King to Green River Knobs following the general direction of the river, and the line from Raccoon to Bear Knobs the ridge dividing the Cumberland and Kentucky rivers. Within this area are the lower portion of Laurel river, the Rockcastle and its various branches, and several lesser streams of the Cumberland. This river, at the crossing of the Cincinnati Southern Railroad, is five hundred and seventy-five feet above sea-level. The highest point within the area, with the exception of King Knob, is Green River Knob.

The outline of the coal fields are crossed in this quadrilateral, and Green River Knob, with several others in the same locality, show the characteristics of the Sub-carboniferous topography. Green River Knob is capped by the sandstones of the Chester Group.

The bases of these knobs, extending, in some cases, their entire height, are of Sub-carboniferous limestone. The slopes are gentle, and often permit of cultivation to the summit.

The higher knobs are capped with sandstone, from which, when exposed, they take the name of sand knobs.

The Green River Knob is two hundred and thirty feet above the next highest knob in the vicinity; it is on the divide between the Cumberland and Green rivers, and is six hundred and eight hundred feet above the creeks at its base on either side. The triangle Green River Knob, Brushy, and Sand Knob includes the head waters of Green river.

Sand Knob is the summit from which flow the Salt, Green, and the branches of the Kentucky. The area extending north from that already described, as far as included in the sketch, is the water-shed of the Kentucky river.

From the stations Pine, Carter, Bald, Collier, and Bear, known as knobs, the country is cut down with steep slopes through the Carboniferous, Waverly, and Devonian formations to the Silurian. This fall or drop-off varies from two hundred and fifty feet at Pine Knob to over seven hundred feet at Bear, and affords an extensive overlook into the Silurian area to the northward. Twelve miles to the northwest of Green River Knob, the streams cut down to the Cincinnati Group. The points noted in the area north of the knobs are nearly on the same level.

The knobs have been seen from points north of the Kentucky river within ten miles of Lexington. In further progress the triangulation will naturally follow around the edge of the Blue Grass or Silurian area, extending over it from the superior points as above shown. The sketch accompanying this description shows the position of the stations, their heights, and their relation to the topography.

The topography is not from actual survey, but is simply represented to illustrate the relation between the triangulation and topographical map.

Points have been located in sixteen counties of the State.

If from any of these stations a survey in detailed topography should be made, the map could be placed in its proper position, and in this manner a complete and accurate topographical delineation would result.

This, with the additional work of latitude and longitude determinations, would furnish such a delineation of the State as would be alike useful in the location of a farm plat or a railroad line, or in the proper representation of an ore or coal outcrop, or of general geological information.

GEOLOGICAL SURVEY OF KENTUCKY.

N. S. SHALER, DIRECTOR.

TOPOGRAPHICAL REPORT

OF A PART OF

GREENUP AND LAWRENCE COUNTIES

FOR

THE YEAR 1874.

BY C. SCHENK.

PART II. VOL. V. SECOND SERIES.

STEREOTYPED FOR THE SURVEY BY MAJOR, JOHNSTON & BARRETT, YEOMAN PRESS, FRANKFORT, KY.

TOPOGRAPHICAL REPORT OF A PART OF GREENUP AND LAWRENCE COUNTIES FOR THE YEAR 1874.

TOPOGRAPHY OF A PART OF GREENUP COUNTY.

On the 7th of May I received orders to prepare myself for a journey to Springville, Greenup county, for the purpose of surveying that part of the county the survey of which was left incomplete by the Geological and Topographical Survey under Prof. Owen in 1861. This territory lies close to the Ohio river, between Tygart's and Indian creeks. I made my arrangements as quickly as possible, reached the ground, and was ready to work on the 13th of May. Previous to other work, I took a hasty reconnoitre of the country, that I might reach a decision as to the best method of surveying to be pursued.

I had hoped that, by the measurement of a small base, and following a triangulation resting upon this base, I might at any rate establish particular points by means of which I might ascertain the exact position of each particular region which was to be surveyed in detail. I did not succeed in establishing to my satisfaction a sufficient number of prominent points of reference. This could only have been done by cutting off the timber on different mountain tops. There were not funds sufficient to have the wood cut from these heights; that is, there were not funds enough for executing work preparatory to a triangulation. Nevertheless, the work was to be completed as quickly as possible. Thus I decided, since there was no other way, to master the survey of details without previous triangulation, by means of polygonal lines drawn through the whole country. For the measurement of angles I had a theodolite, with a telemeter attachment, which latter I applied to measure lengths by means of a graduated staff. The measuring of distances by measuring-rods or by a chain would have gone on but slowly, owing to the unevenness of the ground, and the many obstacles to progress. My instructions were to begin work where Prof. Owen had left off. But as, in my opinion, there were no desirable fixed points to be got, I decided to begin at the Ohio itself.

The portion of Greenup county to be surveyed has a surface of about fifty-five square miles, and, as previously said, is so situated with respect to the Ohio that this river bounds it on the north, while it is bounded on the east by Tygart's creek, partly on the west by Indian creek, and, finally, on the south by Brushy creek.

The principal part of the rain which falls on this surface goes directly or indirectly to Tygart's creek, and thence to the Ohio, while only a small part is brought to the Ohio by Indian creek, and other still smaller rivulets. The principal stream in this region is Schultz creek, with its affluents, Dry Fork and Wingo, which both flow from north to south into Schultz creek. The smaller affluents have but little length, and the mass of water which flows in them is inconsiderable. Almost all the streams run in a more or less easterly direction toward Tygart's creek. They come in order as follows, commencing with the one most to the north: White Oak, Schultz creek, Plum Fork, Beechy and Brushy Fork of Tygart. Indian creek is the only one that runs northward. The amount of water in all the above-mentioned creeks, except Tygart's creek, was, during my stay in the country, small, so that their water-power is not of much importance. On the other hand, Tygart's creek offers a mass of water sufficient to obtain a considerable water-power.

The whole country is hilly, and very much eroded. The many deep valleys which cut through the country occur owing to the proportionately soft material of the Waverly section, which generally forms the main bulk of the hills.

Generally the hills are connected by high ridges. Lost Hill alone, which stands near the junction of White Oak

and Tygart's creeks, is isolated from the surrounding country by a deep gap. There is also a somewhat larger hill round which Tygart's, Schultz, and White Oak creeks flow, and so pretty much isolate it.

Springfield Hill is about six hundred and twenty-five feet higher than the summer level of the Ohio river. The row of hills that run for a certain distance parallel to the Ohio has an extremely abrupt slope towards the north—*i. e.*, towards the Ohio—so abrupt that it is often impossible to scale these hills on that side. On the other hand, the southern slope is much more gentle, and is divided by long ravines that run off towards White Oak creek. The valleys are generally very narrow; Schultz creek occupies the broadest; the area favorable to cultivation is consequently very restricted. This, however, is not true of Tygart's creek, where one finds very finely situated farms. The ridges are generally narrow; still, small plateaux very favorable to cultivation are found on the hills, as, for example, close behind Springville and south of Schultz creek. The land fit for cultivation by the plow is already more or less cultivated. Fruit seems to thrive very well here. I found a young vineyard three years old, belonging to Mr. Nippert, whose grapes looked as sound and full as could be wished. This vineyard is on the sunny side of Schultz creek.

The hills are mostly sandstone. Hence the earth fit for cultivation is mostly sandy; and, as the weather is constantly loosening débris of sandstone from the hills, and the rain washes this débris down into the narrow valleys, the latter are often covered over for quite a distance with a great mass of detritus. This is especially the case with White Oak creek and Wingo, an affluent of Schultz creek. The stream flows often for a certain length under this débris. Water-course and road often occupy here the same ground. It was very difficult to center the instruments here. The crest of the ridges is still mostly covered with timber, which, when I was there, was being cut down in many places to be converted into charcoal and sent to the iron works of the neighboring town of Portsmouth. In the southeastern and western portion of the territory that I surveyed the Hampshire Furnace is, and Globe Furnace was, situated; the iron industry was fairly active. Iron and even fire-clay is found in this district, and the latter is quarried and shipped.

In this connection, the so-called Indian forts of the Ohio valley should also be mentioned. There is one of the Indian forts below Springville. The earthen walls, eight to ten feet in height, which surround the fort, have a parapet of eight feet, and several gates of issue. On the west side the traces of a protected way are clearly perceptible. The fort has the form of a square with rounded corners, and covers a surface of twelve acres. A very small fort, in good preservation, with only one issue, is found above Tygart's creek on a farm owned by Mr. Wm. Biggs.*

I began mapping out my results while I was still surveying. I finished surveying by the beginning of July. I then went home to work at the map. At the beginning of August I received orders to proceed, with assistants, to Louisa, in Lawrence county, and to begin the topographical survey of that county. Accordingly I went thither with two assistants—C. Jeancon and E. Wolff. By the 5th of August we had reached the ground and were ready to work.

The same difficulties presented themselves here, with respect to triangulation, as in Greenup county; and as it was necessary to do the map of this district quickly, there was no other way of going to work except the one already employed in Greenup county—*i. e.*, polygonal lines were drawn over the district, the angles were measured with a theodolite, and the distances with the telemeter.

Lawrence county is bounded on the north by Carter and Boyd counties, on the east by Big Sandy river, which divides it from the State of West Virginia, on the south by Johnson, and on the west by Elliott and Morgan counties.

The principal stream of Lawrence county is Blaine creek. Near it are Cat creek, with its three forks, Irish creek, Cherokee creek, Brushy creek, Little Blaine creek, Hood's Fork, and Keaton Fork, the two Laurels, Rich, Elk, and Morgan creeks, Twin Branches creek, etc.

*Figures of these forts have been prepared for the second volume of Memoirs of the Survey.

At Louisa, county seat of Lawrence county, Tug Fork and Louisa Fork unite to form the Big Sandy or Chatterawha river, which flows thence into the Ohio, at Catlettsburg. Tug Fork forms the boundary between Lawrence county, in the State of Kentucky, and West Virginia. Louisa Fork runs within the State of Kentucky, and divides Lawrence county.

Blaine creek rises on the border line of Lawrence county, carries along in its bed a great part of the water-fall of this county, and empties into Big Sandy river about seven miles below Louisa.

The principal affluents of Blaine creek come partly from a greater distance than Lawrence county, as, for example, the two Laurels, Hood's Fork, Brushy, and Keaton's Fork.

A fork of Blaine creek, Cat creek, has itself three branches —Cooksey, Thompson, and Jordan forks. It rises in Lawrence county at one fountain head. At this fountain head the following streams also rise: Irish creek, Daniels' creek, Cane Fork (a fork of Dry Fork, which is a fork of Little Sandy creek), and Dry Fork, Bell's Trace of Dry Fork, and other smaller streams. Blaine creek itself flows principally in a northeasterly direction. It is first formed by the union of its right and left forks, and then receives on its left the following streams: Cane's creek, Cherokee creek, Irish creek, Daniels' creek, Cat creek, then Long Branch, Newcombe's Branch, and several other small streams, with more or less water.

Beginning at its source, the tributaries of Blaine creek, on the right hand, are Keaton's Fork, Upper and Lower Laurel, Hood's Fork, Brushy creek, Rich creek, Little Blaine creek, Green Briary, Deep Hole Branch, Horsford creek, and other smaller streams. All the tributaries of Blaine creek that have been mentioned are weak in proportion to the territory they drain—they flow abundantly only during rainy seasons. The rain-water runs, for the most part, quickly down the steep hillsides; comparatively little sinks in the ground, and the springs are therefore but scantily supplied. This affords an explanation of the fact that there are here comparatively few abundant permanent springs; but the water of all of them is excellent.

All the streams carry a great deal of sand, and hence Blaine creek itself carries a great deal. It is thus that sand enough is brought to Big Sandy river to justify its name. The depth to which sand lies in the beds of the streams may be surmised from the fact that I could, without any trouble, sink a rod of seven feet to its entire length in the bed of Blaine creek. When it was raining, at the end of the dry season, in the autumn of 1874, and water was flowing in considerable quantities at the head of Hood's Fork, a small distance below no water could be found in the bed of the stream—the sand soaked it all up.

Geologically speaking, this county belongs to the Carboniferous. The rocks of the country are—besides coal and iron beds—for the most part sandstone; limestone occurs only very rarely. Sandstone in general does not offer much resistance to the disintegrating influences of frost and water; so that the hills could not offer much resistance to erosion, and the form of the country is rapidly broken up and ravined.

The hills are about from three hundred to four hundred feet high; they slope downwards with an angle from eight to twenty degrees, and are mostly connected together. On the hills there are very few plateaux, and these are of very small extent. Generally there is only a small ridge on the top of a hill, often scarcely broad enough for an ordinary road. The ridges, furthermore, run in all possible directions, and undergo all sorts of turnings and windings. As rain tears up the roads very much, owing to the light sandy materials out of which they are made, roads have been laid mostly on the ridges or sides of the hills. Recently work has been done in this county towards making better roads, and towards building bridges over Blaine creek.

Since, as has been said, the few plateaux that occur are of insignificant extent, it follows that but little water can sink,

and, as the material of the hills is mostly sandstone or sand, the water is not retained as if the soil was clay. Hence the streams are all more or less liable to dry up during the summer, and therefore their water-power is not of much value. Nevertheless, Blaine creek itself receives so many streams that there is always water enough in it to turn a couple of mill-stones even in the dry season, provided the dams are kept close. There is a very good place for a mill at the so-called Falls of Blaine. Everything has been prepared here by nature to facilitate the utilization of water-power. The place is about two miles from Big Sandy river. Blaine creek receives almost all its tributaries before reaching this spot. At this point, therefore, it has plenty of water in its bed. Furthermore, there occurs here, for a short distance, in the bed of the creek, a harder sandstone, which, at its outcrop, forms the so-called Falls of Blaine. There is already a small mill here, but the position deserves a better one. There is a good foundation for water machinery; there is building material—with the exception of limestone, and even that would not be very hard to procure—inclination enough, and a sufficient mass of water.

The course of Blaine creek is a winding one, and often remarkably so. Especially below the falls, turnings occur. The rocks here opposed the moving of the waters, and so the stream had to force a crooked way for itself. The water often flows back almost to some earlier point of its course. Thus, for example, if you follow the stream, it is ten miles from the falls to the mouth of the stream, while in a straight line the distance is only three and a half miles. At the time when I surveyed this stream the water was uncommonly low, so that it was not very difficult to advance in the sandy bed of the stream. According to what the inhabitants of the country said, there is great danger of sinking into the sand at different places, when the level of the water is higher.

The valleys are narrow as a general rule. The earth, although somewhat sandy, is pretty fertile, and if greater care were given to cultivation, and especially to manuring, it could be kept forever as fertile as new land—that is, land just tilled. All the agricultural products that grow here seemed to me good. The fruit was particularly pleasant to the taste. The hills are still mostly covered with wood; still one often finds hill-sides cultivated way up to the brow of the hill. As for the trees, the ridges of the hills are often partly covered with fir trees; in the valleys we found sycamores, beech trees, maples, the different oaks, such as black oak, white oak, post oak, chestnut oak; on the hill-sides most of the above kinds are found, and also hickory, chestnut, poplar, gum, ash, and black walnut. The use of this timber for fences, houses, instruments, and furniture is limited mostly to the consumption of the country itself. The oak timber is felled, split into staves and the latter are piled up near the streams; when the rainy season sets in they are floated down to a place where they can be loaded on vessels. In this way a great quantity of staves are brought to Big Sandy river. It is said that Blaine creek has a sufficient mass of water to float down saw-logs through many months of the year.

I discovered a mistake in the management of the timber, which I will here mention. It is natural, for example, that a walnut tree cannot prosper if it is surrounded by great beech trees. Now the inhabitants cut down the great trees, whose timber is of use to them, without ever cutting down, at the same time, trees whose value is comparatively less, but which, in growth, are already ahead of the young, belonging to species whose timber is quite valuable. The consequence is, that all the timber that is worth anything finally disappears from the forest, and a new growth comes up very slowly. Some attention should be turned towards giving the young trees of valuable species space to spread in. The region where the two Laurel creeks run over rocks which geologists call Conglomerate, and have cut deep beds for themselves in these rocks, is overgrown with evergreen trees and shrubs, such as spruce pine, holly, ivy, etc., to such a degree that it is almost impenetrable. Very few of the inhabitants know this thicket region thoroughly.

The two above-mentioned streams run partly incased by perpendicular rocks from thirty to fifty feet high. At times one comes on corn mills situated down in the bed of the stream. The road to these has to be more or less hewed out in the rock. The Conglomerate that comes to light here is soon covered up again by overlying rocks. Although the country, taking a bird's-eye view of it, looks pretty ragged and torn, there are no serious obstacles to constructing railroads through it, because the gaps make it possible to build a railroad with only a few tunnels. In Lawrence county there are already several railroads passing through this sort of country.

Besides Blaine creek, Bear creek, in the northern part of the county, carries some water to Big Sandy river. East Fork, an affluent of Little Sandy creek, which rises in Lawrence county, carries its water to Little Sandy creek, a small river which flows into the Ohio at Greenup, in Greenup county.

My work did not extend as far as the other streams which flow into Big Sandy river above Louisa; I cannot, therefore, report anything of them.

Towards the end of November bad weather made its appearance and I suspended field operations. The field notes were then utilized, and a map of the surveyed district made. This map was drawn on the scale of five eighths of an inch to a mile, in order to agree with the map constructed by a previous Geological Survey.

GEOLOGICAL SURVEY OF KENTUCKY.

N. S. SHALER, Director.

ON THE USE

OF

THE TELEMETER

IN

TOPOGRAPHICAL SURVEYS,

BY C. SCHENK.

Part III. Vol. V. Second Series.

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ON THE USE OF THE TELEMETER IN TOPOGRAPHICAL SURVEYS.

As I have already said in my topographical report, I made use of the instrument called the telemeter for measuring lengths during the survey I made of a part of Greenup county and of Lawence county. I was principally moved to apply this means by the topographical relations of the country I had to deal with; for there are in this region but few plains over which a direct measuring of lengths, by means of a measuring-staff or chain, is practicable, with anything like the rapidity which was a necessity with me. Owing to the many bends of the roads, it seemed to me pretty difficult and too inaccurate to use an odometer for measures of length and a compass with sights for measuring the angles. Moreover, an odometer cannot be used in the case of rivers, both of whose banks are covered with brushwood, because the apparatus will not work among brushwood. An odometer consists, for the most part, of a wheel which rolls on the ground, and connected with an indicator, and, when pushed by the operator, rolls further. From the number of revolutions, which correspond to a certain amount of road gone over by the instrument, the distance is read off by means of the indicator.

On straight level roads, and especially on railroads, the odometer is a good instrument for measuring lengths, and is more accurate than a chain. But where the roads are winding and bordered by fences, the use of an odometer must entail a great inaccuracy.

The telemeter, used along with an instrument for measuring angles, offered me the following advantage: from the point where the instrument rested I could measure the distances at the same time that I measured the angles, and I could measure the distances through the air above or beneath the many obstacles that were in the way; in the same way I was able to measure very successfully across a surface of water in the case of streams, a thing which cannot be done with chains, staffs, or odometer. These remarkable advantages threw the balance completely on the side of the telemeter.

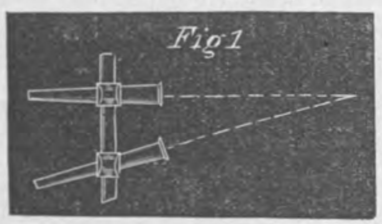
As many looked on with heads shaking disapproval on the method of measurement which I used, and as the telemeter is not sufficiently well known, even by specialists, and in general is not so much used as it deserves to be, I have decided, in accordance with the wish of my chief, to give in the following pages a short explanation of the theory, and its practical application.

THE THEORY.

Theoretically, telemeters are divided, first of all, into two classes. In one class a staff and telescope are used in such a way that the operator looks through the latter towards the former; in the other class of telemeters a staff is altogether dispensed with. We must therefore distinguish between telemeters with and without a staff.

Many telemeters without a staff have been proposed, and even constructed, but so far they have furnished less satisfactory results than those obtained from telemeters with a staff, and are of less value for practical geometry.

Consider the annexed sketch, which is intended to represent two telescopes provided with diaphragms, which can be



moved to and fro on a staff in such a way that the angle which their optical axes make with each other remains constant. It is easy to see that the distance of the two telescopes from each other must be exactly proportional to the distance of a point sighted through both telescopes, assuming that the instrument is not moved. This contrivance would be very excellent if only the condition of keeping the angle of sight constant could be fulfilled with sufficient accuracy. This would require a staff of an uncommon grade to move the telescopes on, and one that would not warp; in short, almost mathematical accuracy would be required in the making of the different parts.

One improvement is to use the so-called angle-mirror or prism instead of the telescope and staff; or, as with the case-sextant mirror, one can deduce the distance from the eccentricity of the alhidade and the measured angle.

Angle-mirrors or prisms can be easily put in position, by means of which the engineer, working on a short basis, can determine geometrically a third (inaccessible) point. An instrument of this kind can even be put in one's vest pocket. The relation of the base, which is to serve for measuring the distance of the point which is to be determined, must be decided before getting ready the prisms, since this relation determines the angle B, according to which the prisms must be drawn.

Let D equal the distance from the point where the operator stands to the object; let b equal the base, and *be* $\frac{D}{b} = m$; so is $\cos B = \frac{1}{2m}$. The quotient m may go up to 3, 4, 5, etc.

Military men have already frequently made experiments with telemeters without staffs. One may claim already to measure accurately with prisms, especially if m is not taken too large.

So much for telemeters without a staff. I now pass to telemeters with a staff.

TELEMETERS WITH A STAFF.

These are divided into two kinds. In one kind the length of staff is constant—*i. e.*, the length of staff that can be used for computation (mostly by means of points whose distance from each other is known) is constant; the angle between the two extreme lines of sight is measured, and from this angle, together with the known length of the staff, the distance of the staff from the point where the instrument stands is computed. In the other kind a portion of staff proportional to the distance is used, and the distance is computed from this portion of staff and a constant, which latter depends on the construction of the instrument used.

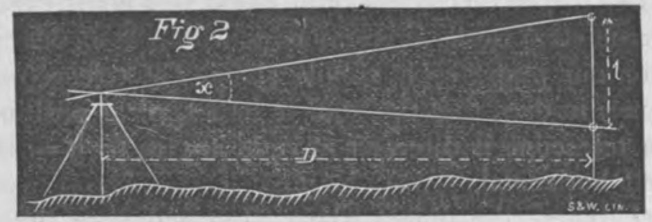
TELEMETERS WITH A CONSTANT LENGTH OF STAFF.

This contrivance consists of a telescope for measuring distances with cross-hairs on one side and a staff of determined length on the other side. After setting the staff and telescope the latter is used to sight the former, and thus the angle, which is wanted in order to bring the cross-hairs from one point of the staff (the blank) to another, is measured. This angle is measured either by moving the telescope, or turning it, or else the horizontal thread itself is moved (Meierstein's telemeter). It is easy to perceive that the accuracy of measurements depends entirely on the accuracy with which the angle is taken, if one leave out of account the correct position of the staff; and in practice this condition is commonly fulfilled by means of finely-cut screws, on which are heads divided so as to determine with accuracy the whole and fractional parts of the necessary rotations, which take place, when the cross-hairs are moved from one target to another.

The telemeters in which, in order to obtain the above result, the telescope is turned through the necessary angle by means of a fine screw, are called Stampfer's telemeters.

As has been already mentioned, the angle which must be known in order to move the optical axis of the telescope during the measuring of the distance from one blank to another, is measured by means of a screw. Furthermore, it is easy to see, that if u equal the necessary number of rotations of the screw, u is inversely proportional to the distance of the staff from the telescope itself; and hence, from the quantity u the distance itself can be determined.

Let l equal the distance between the two blanks on the staff. Let D equal the distance from the staff to the standpoint of the observer. Then, owing to the smallness of the angle of inclination which the lower line of sight drawn to the target makes with the upper one, it is accurate enough to say $D = \frac{l}{tan\ x}$, where x denotes this angle of inclination.



Now the angle is to be expressed by the number of screw-threads that are used in order to bring the telescope through the arc x; and from this one writes down $tan\ x = c\ u$, where c denotes a constant depending of the disposition of the instrument itself, and one obtains $D = \frac{l}{tan\ x} = \frac{l}{cu}$.

The constant c can be determined as follows: A length D is accurately measured on horizontal ground; the instrument is placed at one end of this distance, the staff at the other, and one calculates how great u is when l and D are known, and it will be good to determine u several times. Further, we have $\frac{1}{c} = \frac{D}{l}\ u$ = a coefficient which we can call k, and then we write $\frac{1}{c} = \frac{D}{l}\ u = k$, hence $D = k\frac{l}{u}$.

Stampfer's instruments have the constant $k = 324$, and therefore $D = \frac{l\ 324}{u}$. We now see the results of this equation: l is constant, and different values assumed for u are put together in tables from which one can immediately read off the length D, corresponding to the quantity u.

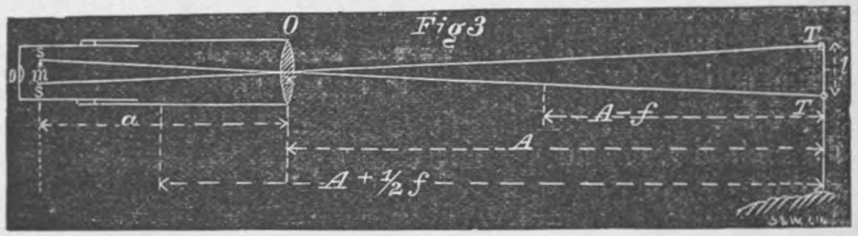
A very great accuracy is claimed for this telemeter by Prof. Stampfer. I have only touched lightly on this telemeter because, unlike the kind I am going to describe, it cannot be adapted to a theodolite which is not specially constructed for the purpose. I now turn to the other kind of telemeters known as Reichenbach's telemeters.

REICHENBACH'S TELEMETER.

This telemeter can easily be adapted to any telescope by drawing two parallel threads across the diaphragm ring of the telescope at any distance from each other.

In order to perceive the way in which this contrivance (the hair micrometer) works in connection with a staff, let us consider, for our purposes, a simple (Kepler's) telescope. Let us assume, further, that the staff is in a vertical position, and that the telescope is directed at right angles to it—*i. e.*, that it is itself horizontal.

Let O denote the object glass. Let o denote the ocular glass. Let m denote the distance between the threads, ss, of the hair micrometer. Let a denote the distance of the position of the image of the staff from the object-glass. Let A denote the distance of the staff itself from the object glass.



Then from the similarity of the two triangles $T\ x\ T$ and $s\ x\ s$, we have the following simple relation: $\frac{a}{A} = \frac{m}{l}$ . . (I).

Further, according to a formula in dioptrics, $\frac{1}{f} = \frac{1}{a} + \frac{1}{A}$, whereby f is meant the focal distance of the object lens. This formula will be found developed in any good text-book on physics. Taking now this latter equation with respect to a, we get $a = \frac{f}{1 - \frac{f}{A}}$. Substituting the value of a in the first equation, we have finally, $A - f = \frac{f}{m} l$ . . . . . (II).

That is to say, the distance from the anterior focus of the object-glass to the staff is proportional to the length of the portion of the staff cut off on the staff by the threads.

Reichenbach's telemeter is constructed with this proportion as a basis.

The proportion between the focal distance f of an object-glass and the distance m between the spider-webs, which

latter are drawn tightly across the diaphragm ring in the telescope is a constant quantity, viz: $\frac{f}{m} = i$. Furthermore, in the same telescope the distance between the axis of revolution and the object-glass is also constant. But the middle point of the axis of revolution is also the middle point of the instrument from which one wishes to measure the distance to the staff. If now, for our further investigations, we adopt a telescope whose object-glass stands $\frac{1}{2}f$ from the axis of revolution of the tube, which is approximately right, then, first, the distance of the staff from the middle point of the instrument is expressed by $A + \frac{1}{2}f$.

If $1\frac{1}{2}f$ is added to both sides of equation (II), and if for $\frac{f}{m}$ its value i is written, we have $A + \frac{1}{2}f = i\,l + 1.5\,f$ (III).

If, then, in a telescope the constant quantities i and f are known, then by means of (III) for every distance of the staff from the middle of the instrument—that is, for every value of $A + \frac{1}{2}f$—a quantity which we will hereafter denote by E—the corresponding portion of the staff can be calculated and the staff divided accordingly.

In the case of Ramsden's eye-piece, which is here most commonly used, and in that of Kepler's telescope, or by the excellent Kellner ocular, which I now use, this formula holds true without exception. In the case of Hughen's telescope, however, the intervention of the collecting lens causes the rays coming from the objective glass to be drawn together; and in this case, to complete our investigation, further considerations are necessary. Since, however, Hughen's eye-piece is but little used in this country, I will not stop to investigate it here; still, I will add, that, for my own part, I have hitherto used a Hughen's eye-piece, and that I shall be glad to help any one who desires explanations about it.

The eye-piece, mostly used with measuring-telescopes here in America, is, so far as my experience extends, the so-called terrestrial or Rheitas eye-piece, which may be considered as arising from a combination of Ramsden's and Hughen's. This eye-piece is like the simple one, or like Ramsden's, in that there is no collecting lens between the cross-hairs and the object-glass.

When one wishes to make a division of the staff according to the formula given above, it should be observed that if the threads are placed much apart, a long staff is needed, while if the threads are placed close to each other, a small staff suffices; small staffs, however, give less accurate results than long staffs, and many persons hold that one should not take $\frac{f}{m}$ larger than 70.

This value is not very convenient, especially because it requires a long staff that must be divided in a special way. If 100 is used as unit of division, one has the advantage of being able to use every leveling staff for measuring distances, although, indeed, the accuracy of measurement is somewhat less.

I use 100 as the unit of division, and, therefore, for a distance of 1000 feet, I need a staff about 10 feet long.

Let us now investigate the case where we wish to use for measuring distances a leveling staff that is already divided, and let us see what the practical results would be.

We have given the leveling staff with decimal division, therefore we must have $i = 100$.

We wish further to measure the focal distance of the objective glass; this can be done with sufficient accuracy by means of compasses; after a distant object—a star—has been sighted to that there is no parallax, one has only to measure the distance between the object-glass and the diaphragm.

We have now $i = 100$, and we have also determined f. We can, therefore, from equation (III) or equation (II) or from $\frac{f}{m} = 100$—calculate the distance between the threads, and then place the threads in position. It is necessary to calculate the distance between the threads as nearly as possible, in order that the threads may be placed in their proper position as nearly as possible, so that it may not be impossible to

effect the small correction which is mostly required later, and which should be rendered possible by means of some contrivance such as a screw. For, with ordinary means, it will be impossible to place the threads with the accuracy which does not show itself till under the magnifying power of the eye-piece.

When we have placed the threads in position upon the diaphragm ring, and the latter in the telescope, we can go on to investigate what the telemeter accomplishes and with how much accuracy it works.

First of all, we have equation (III), viz: $E = il + 1.5\,f$ to take into account, and to determine the portion which must be used for certain distances E.

If, for example, we make E successively equal to 100, 200, 300, etc., the above equation solved with respect to l gives for

$$E = 100, \quad l = \frac{100 - 1.5\,f}{i} = 1 - \frac{1.5\,f}{100}$$

$$\text{for } E = 200, \quad l = \frac{200 - 1.5\,f}{i} = 2 - \frac{1.5\,f}{100}$$

$$\text{for } E = 300, \quad l = \frac{300 - 1.5\,f}{i} = 3 - \frac{1.5\,f}{100}$$

that is, *when the staff is* 100 *feet off the portion of staff used is* 1 *foot* — $\frac{1.5\,f}{100}$ *in length;* when the staff is distant 200 feet from the centre of the instrument *the length of staff used is* 2 — $\frac{1.5\,f}{100}$ *feet, and so on; so that a portion of staff less than* 1 *foot corresponds to the first* 100 *feet, and exactly one foot more of staff is required for every additional* 100 *feet.*

The point on the staff which is determined by the quantity $\frac{1.5\,f}{100}$ has been fitly called the zero point. In this connection I should mention, that for this determination I supposed a telescope, whose pivoting axis was ½f from the object-glass; if this quantity were different, it would have to be introduced with its proper value. For example, in the case of a telescope, the focal distance of whose object-glass was six, and between the axis and object-glass three, decimal inches, the portion of staff corresponding to a distance of one hundred feet would be 0.991, and for two hundred feet, 1.991, etc.

When this zero point has been so computed it is marked on the staff itself, and, in measuring, the upper thread is always directed to this zero point, while, by means of the lower thread, the distance is read off on the staff. If one has to work with a staff without zero point, it is necessary to add to the distance taken between any numbers the constant 1.5 *f* in order to get the correct distance. Accordingly, as I have here pointed out, it is entirely wrong to place one's threads in such a way that, for a distance of one hundred feet, they cover just one foot of the staff. This arrangement is assumed by many to be correct, as I found to my grief; it is even set forth as correct in instructions about the use of instruments. One has only to use an instrument with a considerable focal distance in order to perceive, that if the threads cover one foot of staff for a distance of one hundred feet, the measurement of great distances becomes very inaccurate. With my telescope I would have made an error of fifteen feet in 1,000′ distance if its threads had been set in the faulty way I have mentioned.

When one's telemeter has been put in order, and the staff also is in order, the zero point having been determined, the next thing is to measure on an even plane, as accurately as possible, a suitable extent of ground from five hundred—one thousand feet with a staff or chain. A straight railroad rail is peculiarly suitable for a good measurement, which can be accurately taken by means of a steel tape measure. Next the instrument should be placed at one end of the measured strip, the distance staff should be set vertically up at the other end, and the engineer should examine whether the threads have the separation which corresponds to this distance, and whether they cover exactly the zero point above, and—for example, for a distance of one thousand feet—the ten-foot partition counted from above.

A variation from the present disposition of the instrument can be obtained, if necessary, by pushing the slits on which the threads rest, which movement is practically effected by adjusting screws.

It will be good to try the telemeter on many lengths that have been accurately measured, and it is specially advisable to measure small distances with it. If all comes out right, one can trust with safety to his telemeter.

The above remarks were made under the supposition that the staff was placed vertically and the telescope horizontally. In practice such a use is seldom made of the instruments, except in leveling; on the contrary, the sights are inclined either upwards or downwards. We have still to investigate in what way the results of measurement are modified by this departure from the previous hypothesis.

We have further to consider whether the staff shall be placed vertically; or perpendicularly to the line of sight of the telescope.

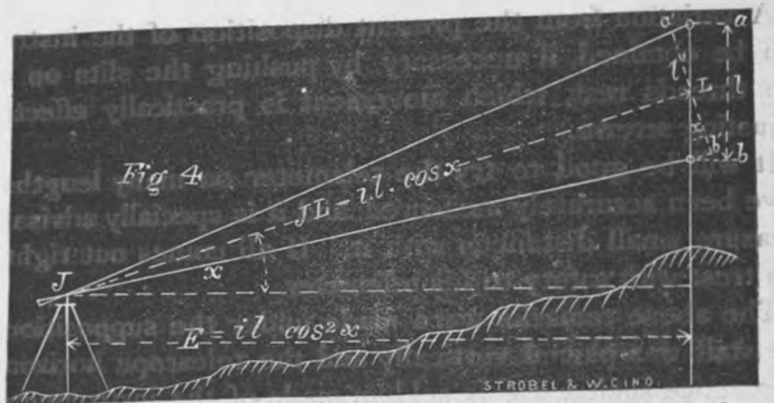
The staff can be placed vertically by hand, by a level, by a plumb-line, or by balancing the staff on a point placed under it. I make use both of balancing and plumbing, according to the nature of the work.

The staff can be made perpendicular to the line of sight by placing a *diopter* on the staff, and then sighting the instrument from the staff.

REDUCTION OF OBLIQUE LENGTHS.

If one sights a vertical staff under an inclined angle, then, on account of the oblique sighting, a larger part of the staff will come between the threads than corresponds to the direct distance. The length of the portion of staff so sighted can be read off directly. The angle x, under which the staff is sighted, can also be read off. Therefore, we have the data for reducing.

The portion of staff $a' b'$ corresponding to the distance $J L$ is the correct one, while as a matter of fact the greater portion $a b$ is read off, and we wish, therefore to deduce $a' b'$ from $a b$.

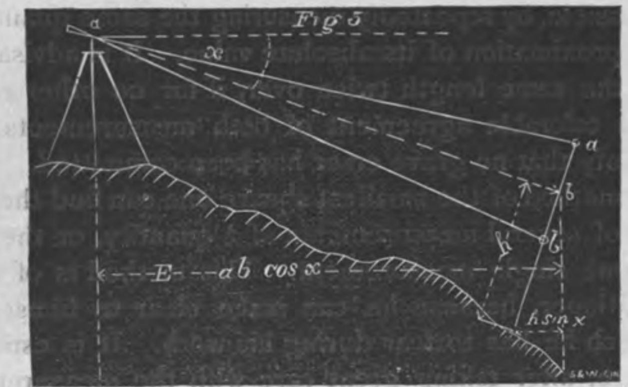


Owing to the smallness of the arc which $a' b'$ subtends, $a' b'$ can be expressed with sufficient accuracy by $l' = l \cos x$, when $ab = l$ and $a' b' = l'$ the value l' so obtained corresponds to the oblique distance $J L$, which is denoted by the expression, oblique length. This quantity, $J L$, however, must still be brought down level with the horizon; it cannot yet be called the correct horizontal measure. This quantity $l \cos x$ must itself be reduced, which is done by multiplying again by $\cos x$, so that we have $E = il \cos^2 x$.

The quantity $\cos^2 x$ can be very easily deduced from x itself. Thus, if it is wished to carry out the multiplication in a graphic way (which is a very convenient operation if one wishes to put the lengths on a scale, in order to introduce them into a map). one has merely to calculate the values of $\cos^2 x$, to consider them as *cos* of an angle, and to set these angles down in a diagram, by means of which the whole reduction can be completed with compasses. (Jordan's diagram.)

If the staff is placed at right angles to the line of sight, the necessary reduction to horizontal values can be performed by the help of the following considerations.

If $a\ b$ again stands for the portion of the staff covered by the threads, then in both figures the horizontal correction will simply be: $a\ b \cos x = E$. But it will be perceived that, owing to the oblique position of the staff, it rests at another place than that which E requires. This reduction depends also



on whether x is an angle above or below the horizon, and on how high on the staff the middle line of sight reaches.

If we call this length, which changes for every distance, h, then, besides the above reduction, $h \sin x$ will have to be added to E for an angle of elevation, and subtracted from E for an angle of depression, in order to determine the point where the staff touches the ground.

The data of reduction for a given staff, and for different values of E and x, have been tabulated, and by means of these tables the reduction can easily be effected.

With respect to the telescopes that are to be used for measuring with telemeters, they must be of the best quality, and must possess great clearness, and especially definition, together with great magnifying power.

ON THE ACCURACY OF LENGTH MEASUREMENTS.

Experience shows that in all measurements a deviation occurs from the real length. I do not wish to include among errors so committed those which arise from inaccurate observation and inaccurate reading; such mistakes can be avoided; I refer to mistakes arising from the imperfection of our tools and senses. An idea of this kind of error may be got by measuring several times a length of 100′ with a 1-foot measure, and finding that each result deviates slightly from the preceding one.

It is possible, by repeatedly measuring the same quantity, to get an approximation of its absolute value. It is advisable to measure the same length twice over, if for no other reason, because a tolerable agreement of both measurements gives the certainty that no grave error has been committed.

By the method of the smallest square one can find the mean error out of several measurements of a quantity, or the mean error of one single measurement. This method is of use to the practitioner, because he can make clear to himself the errors which he has to fear during his work. It is especially used where, after taking great care with the measurements, one wishes to bring the final result still nearer the probable true value.

In the following tables are arranged, as far as I know them, the results which have been obtained by the method of the smallest square, from the most accurate and from less accurate measurements:

MEASUREMENT OF BASES.

Mean errors in a single measurement of the length of one kilometer = 1,000 meters = 3,280 English feet.

Year.		Millimeters.	English inches.
1736.	Base of Yarouqui, in Peru, two measurements with wooden staves, from 15 to 20 feet long.	16.4	five eighths.
1736.	Base of Tornea, in Lapland, two measurements with wooden staves	20.2	eleven sixteenths.
1739.	Re-measuring of the Picard base under Juvisy by Cassini	63.2	two and a half.
1819.	Schwerd's small Speyer base, two measurements, 859.4409 meters long	1.5	one sixteenth.
1834.	Base line of the measurement of a degree in East Prussia	2.2	three thirty-seconds.
1846.	Base line near Berlin for the coast survey, two measurements	1.6	one sixteenth.
1858.	Spanish base of Madridejos, twice measured	0.4	one forty-
1860.	Small Spanish base of Ivice, measured four times	0.3	[eighth.
1868.	Austrian base in Dalmatia, two measurements	0.7	

MEASUREMENT WITH STAVES.

The mean error of one measurement derived from measuring twice, the lengths measured being different.

Length in feet.	Mean errors of a measurement in decimal inches.
300	1.098
600	1.553
1,000	2.005

CHAIN MEASUREMENTS.

This is derived from over 500 measurements taken twice of lengths going up to 1,000 feet, with chains of from 30 to 50 feet long:

MEAN ERROR OF ONE MEASUREMENT IN DECIMAL INCHES.

Length in feet.	On sandy ground.	On loamy ground.
300	5	3
600	7	4
1,000	10	6

Whence it is evident that measurement with a staff is three times as accurate as measurement with a chain.

In ordinary measurements, which are made with somewhat less care, the mean error proves to be as follows: on hard ground, 1 ÷ 1000; on washy or soft ground, 1 ÷ 500; on common ground, 1 ÷ 700.

When a chain is used, its tension should carefully be observed in order to compensate it. The depression of the chain, owing to careless stretching, produces an error which increases with the square of the depression.

OF THE MEASUREMENT OF DISTANCES BY MEANS OF REICHENBACH'S TELEMETER.

I obtained the following results on a railroad track on which the distances had been accurately measured with a steel ribbon; the distance was read off three times for each place where the staff was put up:

WITH THE TELEMETER—MEASUREMENT.

Length measured with the Steel Ribbon.	First.	Second.	Third.
100	100	100	100
200	200	200	200
400	399.5	400.5	400
600	599.5	600	599
800	799	799.5	800
1,000	999	1,000	1,000
1,200	1,199	1,201	1,198

Whence the deviation from the accurately measured length is at the utmost 1 ÷ 600. These measurements were made with great care, in quiet weather, and with good light. Such accuracy is surely not to be obtained by a day's work. According to the results obtained by other observers, the accuracy amounts to somewhat less; the error is given as from 1 ÷ 400 up to 1 ÷ 300. But, taking merely the accuracy obtained with the last error, and the telemeter is still a very good instrument for topographic work.

Moreover, it is easy with a telemeter to take several readings instead of one, and so to increase the accuracy; so much so that four readings double the accuracy.

It is of special importance in the measuring of distances that the staff, if it is used in a perpendicular position, should be satisfactorily held perpendicular; and this is pre-eminently true on sloping ground, since the very considerable errors are made by carelessness in placing the staff. If, for example, a ten-foot staff is held so that its deviation from the perpendicular amounts to one foot, and if the staff is sighted at under an angle of five degrees, this would already bring about an error of one per cent. in the length.

With a telemeter we have also to consider the state of the air with respect to rest or motion, the light, and the condition of equilibrium of the lower layers of air. In summer, during the hot part of the day, the sunlight brings about such a trembling of the images of the sighted object that sighting and reading off become very difficult operations. When the sky is clouded the objects are quietest, and one can then work very comfortably.

The advantages of the telemeter are specially manifested in a favorable light in making topography which must be quickly completed, because the measurement of distances takes place from the same stand of instruments from which other objects, such as houses, etc., are placed in; as unevennesses, bushes, etc., are disregarded, as long as one can see through and over them. If one has to survey a stream, and is unable to see along on the shore, owing to weeds,

trees, or plantations, one has only to go to the water, and if one can only get a place to stand upon, there is nothing to prevent the measurement along or across the water.

The rapidity with which the work progresses depends naturally on the ground and material which one has to deal with. From six to eight miles is a good day's work. Sometimes I have measured ten miles in a day.

GEOLOGICAL SURVEY OF KENTUCKY.

N. S. SHALER, DIRECTOR.

REPORT

ON THE

TIMBERS OF THE TRADEWATER REGION

CALDWELL, LYON, CRITTENDEN, HOPKINS, WEBSTER, AND UNION COUNTIES.

BY LAFAYETTE H. DEFRIESE.

PART IV. VOL. V. SECOND SERIES.

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INTRODUCTORY LETTER.

NEW YORK, September 17, 1877.

Professor N. S. SHALER, *Director Kentucky Geological Survey:*

I submit herewith a report upon the timbers of the Tradewater River Region of Northwestern Kentucky. Owing to the favorable situation of this region, to its geological character and the minute but important changes in its surface soils and to the drain which has been made upon its timbers within the last few years, which is liable to increase rather than diminish in the future, I know of no part of Kentucky that furnishes a more interesting or important field for the study of some of the problems connected with the growth, decay, and succession of timbers. Such of these problems as my limited time and opportunity would permit me to consider, I have briefly discussed in the following pages.

I wish to acknowledge my indebtedness, and that of the Survey, to the Elizabethtown and Paducah Railroad for facilities of travel afforded, as well as to the many private individuals who, by their kindness, have helped to forward my labors.

Very respectfully yours,

LAFAYETTE H. DEFRIESE.

REPORT ON THE TIMBERS OF THE TRADEWATER REGION—CALDWELL, LYON, CRITTENDEN, HOPKINS, WEBSTER AND UNION COUNTIES.

GENERAL REMARKS.

I need say but little in regard to the method of timber study pursued in these counties, as it is almost identical with that described in a former report on the timbers of neighboring counties.* In speaking of and tabulating the characteristics of the timbers of different localities, it will be noticed that I have changed my points of study to suit the changed conditions of the timbers. For instance, where there is a heavy drain constantly made upon the forests by cutting and floating out timbers, I have tried to find out about the rate at which valuable timbers are disappearing, and to compare that with the character and growth of the young forest trees, in order to arrive at the effects of such drain upon the future forests of Kentucky. Again, in another locality, where some other cause is operating to produce other effects, or where similar effects are produced by different means, I have paid especial attention to this changed condition of things and so on.

The valuable timbers in this part of Kentucky are chiefly the following, which are important in the order given: white oak, liriodendron (yellow poplar), white and black ash, white hickory (or second growth hickory of any variety), white elm, black walnut, post oak, sweet gum, bartram oak, and cotton tree. And when I say that these timbers are important in the order given, I take into consideration their value as a source of wealth to the State, which depends upon three things: the market value of the timber, the amount of it found in the

*Report in volume II, this series.

country and the use to which it is put. Of course, the market value of walnut is greater than that of any other timber in Kentucky, and, if that alone were considered, walnut would head the list of valuable timbers; but the comparatively small quantity of it now found in the country places it low in the scale. White oak must, therefore, be considered the most valuable timber of the Kentucky forests. In this part of Kentucky, it is the principal forest tree along all the streams, and on the more or less level, sandy soils. But, as a rule, in these counties it is not spread over the hills as in some parts of the State. On lands not more than twenty-five to forty-five feet above local drainage, and on loose sandy soils at almost any height above drainage, the white oak forms about 40 per cent. of the forest timbers. In hilly regions, however, the white oak usually gives way to black oak, scarlet oak, and post oak, at a height of about forty-five feet above local drainage. But not all of this white oak, scattered along the streams and through the woods of the interior part of the State, is available at present; nor is it likely to be for years to come. A large part of it must be looked upon merely as a reserve for the distant future, when the more convenient forests shall have been stripped of their white oak wealth by the enormous drains now made upon them. And in the following pages, unless the contrary is distinctly stated, I shall confine my discussion of the rate of disappearance of white oak timber from the forests to available white oak—that is, to white oak that is sufficiently convenient to some railroad, or to some stream large enough to float it out, to be procured without too great outlay. It should be kept in mind that the supply of this timber, which is too remote from present means of transportation to be considered here, inasmuch as there is no drain upon it and cannot be for years to come, is almost without limit. This possible reserve, however, should not be allowed to blind the people to the dangers that threaten the white oak in all places where it is exposed to heavy drains. For, after all, the expense of reaching timbers so distant from means of conveyance would cause a necessary resort to them to be almost as

great a calamity as the total disappearance of those timbers. Besides, whenever a resort to such timbers *does* become necessary, then the same rates of disappearance will apply to them which are now found to apply to those timbers subject to a present drain. For the present, therefore, I shall speak chiefly of available white oak, and from this point of view.

The valuable white oak timber of the Tradewater region is to be found within one or two miles of Tradewater river, on either side, and low down on the larger tributaries of that river, where the streams are of sufficient size to float out the logs. The same may be said of all the other timbers which I have given as the valuable ones, with the possible exception of the post oak, which grows abundantly along all the hill-tops. The question of immediate interest is, therefore, what is the *present* timber supply, and what the rate of consumption in these available localities? If the supply seem inexhaustible to one who rides hurriedly through miles and miles of massive white oak, sweet gum, hickories, etc., all the more impressive, if not alarming, is the truth which closer investigation forces upon him. Especially is this so of the white oak and liriodendron (yellow poplar). A careful calculation, extending along the whole available part of the Tradewater river and its tributaries, convinced me that about 30 per cent. of the valuable white oak, which forms so large a proportion of the forest timbers in these localities, has been cut out within recent years, while the young forest will furnish only about 5 per cent. of this timber to take its place. So that, since the drain upon the timber resources of the Tradewater region commenced, about 25 per cent. of the entire available white oak timber has disappeared. And even of that left standing, the timber found is larger and more valuable in proportion to its distance from a stream capable of floating it.

The effect of this drain upon the liriodendron (yellow poplar) is still more striking. In all the St. Louis limestone regions of Caldwell, Lyon, and Crittenden counties, along streams where yellow poplar ought to flourish, only now and then could a tree be found. When I inquired if it did not grow in this region, I was invariably informed that there once was a great deal of poplar in these localities, but that it had all been cut out. The same is true, to an alarming extent, throughout the whole Tradewater country. High up on the Tradewater river, and on small and inconvenient tributaries, considerable quantities of liriodendron are to be found; but I know of no convenient locality in which any considerable body of really valuable yellow poplar timber now exists. It is perfectly safe to say that fifty per cent. of all the available timber of this kind has been cut out.

The sweet gum seems to be plenty, and the white elm more or less so; but it was impossible to form any idea of the future forests of these timbers. The drain upon them now, though considerable, is largely local. The black walnut is now mostly second growth, and seems to be small, rough, and limby. The reason is, I think, that it grows up only in open places, where it does not have to compete with other timbers. It is therefore confined to fence-rows and road-sides, where the ground is hard-trodden, or else to waste places where the soil is exceedingly poor. This gives it the character of a dwarf or scrub timber, which the old forest growth did not have.

DRAINS ON TIMBERS.

The principal drain upon timbers of the Tradewater region at present, outside of the local saw-mills to be found along all the streams where good timbers abound, is made by the spoke factory of Booth, Dulaney & Co., at Kuttawa, Lyon county. It is called a spoke factory, though in reality the firm manufacture, in addition to wagon and buggy spokes, hubs, felloes, axles, etc., nearly all modern implements used about the farm, such as axe-handles, broom-handles, ox-yokes, ox-bows, etc. A large part of the rived spoke timber (white oak) used by the factory is obtained from the Tradewater region. I was informed by a gentleman who has had many years of experience in that branch of business, that the best and most durable white oak timber in the United States comes from the Tradewater and its tributaries.

Probably the reason of this is, that the white oak which comes from too far south grows up rapidly, and, exposed to long summers and short winters, is too sappy for the best wagon timber, while, on the other hand, that obtained from too far north, owing to slow growth and exposure to long winters, is too brittle for long wear. This is merely a suggestion, however. At any rate, the timbers from this part of Kentucky are in great demand; and while I was in Kuttawa I met Mr. S. N. Brown, of Dayton, Ohio, who owns one of the largest hub and spoke factories in the West, who was then in Kentucky preparing timbers to ship to his factory.

Messrs. Booth, Dulaney & Co. use post oak altogether for heavy wagon hubs now, and say it outwears any other timber that can be used. Certainly their supply of that is unlimited. A hill variety of white elm is used for buggy hubs, and white hickory alone for buggy spokes and rims. White hickory is also used for wagon axles, double-trees, etc., and the white oak for spokes, bolsters, sawed felloes, etc. The firm employ one hundred men constantly, thirty of whom are engaged in cutting and floating logs, the products of which are shipped to nearly every State in the Union. They pay from $5 to $7 per thousand feet for logs rafted to them, or from $10 to $15 per acre for good timber lands. Except the white oak, they bring most of their timbers from up the Cumberland; but when one considers what an amount of white oak timber is here worked up into wagon materials monthly, he can easily see what an enormous drain is made upon a region whose available timbers are limited. Add to this the almost countless little sawmills scattered along on every branch and creek in this whole region of country, which can easily shift from place to place as the timber is exhausted, and one can readily comprehend what a sweeping destruction of forest timbers is going on. Strangely enough, as yet the great factories of Paducah have not turned their attention toward the Tradewater as a convenient source of timber supply for them; but we may expect this as soon as the Cumberland and the Tennessee river timbers begin to be exhausted. When this time comes, should it ever come, an additional drain of 6,000,000 feet of timber per year will be made upon the Tradewater country. It is needless to say that, with such an additional demand upon it, the valuable available timbers of this part of Kentucky would be exhausted in a few years. For I shall show, further on in this report, that there is little hope of a young forest which can take the place of the old one now passing away.

SPECIAL TIMBER VARIATIONS.

It should be noticed that in a former report* I spoke of a peculiar, and, in many respects, remarkable belt of timbers crossing the Hartford and Cloverport road, about twelve miles from Cloverport, and running a slightly varying east and west course across Breckinridge and Ohio counties. The ground is high and nearly level, and the soil a loose, damp, sandy formation. The belt is about five miles wide. In passing down the Tradewater I found a timber belt, which, from its width, the formation of the soil, and the character of the timbers, I believe to be a continuation of the belt formerly spoken of. It is about six miles wide and crosses Hopkins county between Garnettsville (now Dalton) and Providence. In this strip of woods the white oak, liriodendron (yellow poplar), white and blue ash, white hickory, black walnut (most of which has been cut out), are unsurpassed in size and beauty. They form a marked contrast to the timbers on either side of the belt. If these two belts be the same, as I believe them to be from similarity of characteristics, we have the remarkable phenomenon of a belt of the finest timbers extending, so far as observed, for more than one hundred miles, through other forests where the timbers are good, but not extraordinary, and following the general course of the Ohio river, though at no point, so far as I know, nearer to the river than ten miles. The belt is certainly not a level-topped, sandy range of hills bordering the Ohio, for there are numerous hills and hollows between it and the Ohio, on none of which is the timber especially noticeable.

*See repo.t volume II, this series, page 7.

But there is one difference between this timber belt east of Green river, and the same (if it be the same) west of that river, which deserves especial attention: that is, the belt east of Green river is remarkable for its massive chestnut timber, often more than five feet in diameter, which forms a large per centage of the forest trees. West of Green river, however, I was not able to find a single chestnut in all the counties passed through, and all those of whom I inquired said that they had never seen a chestnut on the west side of Green river in that part of Kentucky. Certainly this is remarkable. The geological formation on the opposite sides of Green river is exactly the same, so far as I could determine, and is, so far as the surface is concerned, mostly the sandstone of the coal measure group. The regular pebbly conglomerate seldom appears here, even on the hill-tops. Certainly, in the belts spoken of, I could detect no difference whatever. Both (if they be two, and not, as I think, the same) are high, level, or nearly so, damp and sandy, and the massive timbers of the two are exactly the same, with the exception of the chestnut. If it be true, as I was informed (and it certainly is, as far as I was able to investigate), that no chestnut is found in this part of Kentucky, west of Green river, the reason why the chestnut should jut up against this river, and find in it a perfect barrier to its westward course, is worthy of investigation. With the limited time for study at my command, I could discover no cause for such a phenomenon.

While speaking of timber variation, I wish to notice the question of the succession of forests in Kentucky and to mention the results of some observations made by me in that direction.

In the report before referred to (vol. II, this series), I gave my reason for believing that the present forests of white oak will be supplanted, in the future, by black oak, red oak, Spanish oak, and such timbers, of which black oak will be the leading timber. Two questions present themselves to me in this connection for solution: 1. Is it merely the white oak that is supplanted by the black oak, while of other timbers each will be succeeded by one differing from itself, but not necessarily black oak; or is black oak taking the place of all timbers alike? In other words, will the future forests of Kentucky consist of about the same timbers as the present forests, except that each timber will appear in the place of some other, and in a different locality, or will some one timber supplant all alike, and be the leading forest tree of Kentucky in the future? 2. In case it should be found that no regular rotation of forests is taking place, but that some one timber is supplanting all others, in what way can the present distribution of timbers be best secured?

In reference to the first question, I noticed that in all those localities along the Tradewater, if the immediate borders of the streams be excepted, where the white oak forests are now finest, but where the present timbers are fast disappearing on account of the drain constantly made upon them, that the undergrowth has about the same per centage of black oak that the present forest has of white oak—on an average about 40 per cent. Very little white oak, indeed, will appear in the future forest, even in regions where now it most appears. I then noticed carefully localities where the present predominant timber is black oak, red oak, post oak, or hickory, and in each case I found that the undergrowth contained from 25 to 40 per cent. of black oak, while no white oak at all appeared. It seems to be an inevitable conclusion, therefore, that the present valuable timbers of Kentucky are disappearing, and that the comparatively worthless black oak is to be the universally predominant tree of the future. This is not true of the hickory, of which there will be as large per centage in the future as there is in the present forests; while of white elm and white ash, on account of the comparatively small proportion of these timbers, except in somewhat low lands, I found it impossible to obtain data enough to warrant a conclusion. My opinion is, that they, too, will almost disappear when those in the present forest are removed or die down. Of the swamp timbers proper, such as sweet gum, sycamore, red elm, maple, etc., I see no reason to expect a change; but of the white oak

and liriodendron (yellow poplar), which, after all, are the great staple timbers of Kentucky, I believe the time will come, and that far sooner than those who have not investigated the subject suspect, when they will disappear entirely from our forests, unless some earnest effort is made to avoid such a calamity.

The second question then presents itself, viz: How can the present variety and distribution of Kentucky timbers be maintained? I have two methods to suggest, neither of which will, I fear, be acted upon until the people become alarmed at the condition of their forests, and show more energy in caring for and perpetuating them than they have shown in the past. One of these methods is to plant trees of the same kind as rapidly as the old timbers are cut away, or as the land is exhausted and "turned out," and to keep down other growths until the planted trees get a start. This needs no discussion. It is the method that *must* be adopted in introducing a new variety of timber into a forest, as well as in perpetuating some varieties. I believe that the black walnut, for instance, can be preserved only in this way.

The second method, which can be employed only where, as is the case to a large extent in Kentucky, the present forest is the kind desired, is perhaps the more available of the two. It is well known to all observers of timber growth, that if a tree be cut down toward the spring of the year, just before the sap begins to rise, a large number of shoots or "sprouts" will spring from the stump of the fallen tree. If those who are cutting timber to float out would cut as late in the winter as possible consistently with meeting the spring freshets, the sap rising in the stumps of the lately cut trees would cause this growth of shoots. Then if the undergrowth of the different varieties, which already have such a start as to soon smother the tender bushes springing from the stumps of the fallen trees, were merely cut away, these bushes would get such a start as to hold their ground, and the present forest timbers would be preserved in about their present proportions. This would really require very little labor; and, while I have never seen the experiment tried on a large scale, I believe it would be entirely successful. Certainly, if the present forests of Kentucky can be preserved by so small an outlay of thought and labor now, it is of the highest importance to the people to see that this source of wealth to the State is not allowed to waste away. Otherwise, their descendants of a few generations hence will be compelled to go through the slow and laborious process of planting and cultivating those very timbers which are so abundant to-day, and which, by a little care on the part of their forefathers, might have been left to them as a rich inheritance.

SOME EFFECTS OF TIMBER CLEARING.

It is a lamentable practice in most farming regions of Kentucky, when a piece of ground becomes somewhat exhausted, to clear another piece and tear down the fence of the former to inclose the latter, leaving the worn-out lands exposed to the ravages of stock, in addition to washing rains. The consequence is, that cattle eat down each little bush or weed, on the lands thus suddenly exposed, as fast as it appears. As the soil has been lately cultivated, and is comparatively loose, a few heavy rains start myriads of "gullies" in the ground, whose only protection against such washes was removed by "turning the land out," and allowing the cattle to eat down the little herbage and bushes that might otherwise have cemented the surface soil. A few years of such exposure gives the "washes" such a start that no amount of care and labor can preserve the land from utter destruction. If one reflects upon how many farmers there are in Kentucky, and that the vicious system of culture pursued by them consists, in the greater part of the State, in thus clearing a piece of land, working it without manure or much rotation of crops, year after year, until exhausted, a process which, on an average, requires only five or six years, when they abandon it and clear new ground, one can realize how many acres of the land of Kentucky are thus annually "turned out." Aside from the destruction of valuable forests entailed by such a system of cultivation, the effects upon the soil and climate of the regions thus cleared are very

serious. Granted that in the course of years other forests will spring up in such districts, I have elsewhere shown that these new forests will be comparatively valueless, so far as the timbers are concerned. Of course, their presence would prevent the further washing of the soil and change of climate produced by barrenness, but nothing more. In fact, however, I see little hope of a worn-out soil thus exposed ever reclothing itself with timbers of any kind. Timber growth upon such exhausted soils is so slow that its battle with washing rains would be doubtful, even with the best protection that could be given it; but when to the washing of rains is also added the ravages and trampling of cattle, and other such things incident to a totally exposed piece of once cultivated soil, I believe that the chances of a new forest growth are exceedingly poor. I have myself seen a piece of exhausted land that had stood thus, as I was informed, for twenty years. In it I measured washes fourteen feet deep and twelve feet wide, while almost every square yard was crossed by a "rut" or "gully" of greater or less size. A few scraggy persimmon bushes occupied the still unwashed spots; but it seemed to me inevitable that the entire two hundred acres of once fertile ground would soon have its surface soil completely washed away. If the farming lands of Kentucky were level prairie lands, the facts here spoken of would not be so serious; but, on the contrary, the ground is hilly or rolling, and the effects of reckless destruction of forests on such lands are always fatal. I have not seen these effects better stated than in the London Spectator of June 16, 1877, which says:

"The evidence that the great floods which have from time to time, during the last half century, been so destructive in Switzerland, and in many districts of France and Italy, have been mainly caused by the felling of the forests on the high grounds, appears to be overwhelming. In the department of the Loire especially, it was universally remarked, that the wooded grounds suffered no change, while in the denuded districts, the whole soil of cleared and cultivated fields was swept away, and the rocks laid bare. The same was seen in the upper Rhine in 1868. The clearings in the province of the Ardeche have produced the most melancholy results within the last thirty years, one third of its area having become barren; and new torrents had, in 1842, destroyed 70,000 acres of land, an evil which has been going on ever since that time. The denudation of the crests of the Vosges has done infinite harm in Alsace. Many places in Provence, rich and inhabited half a century ago, have become deserts. Thousands of torrents have been formed within the last dozen years on the southern flank of the Piedmontese Alps and in Dauphiny, and grassy slopes have been converted into stony chasms by the cutting of the woods above. In the department of the lower Alps, between 1842 and 1852, 61,000 acres went out of cultivation from this cause. In Italy, the demand for Italian iron during the wars of Napoleon I, the trade with England being cut off, necessitated vast cuttings of wood for fuel, and the effects are felt to this day, especially in the valley of the Po. In fact, there is scarcely a country on the continent of Europe in which the reckless destruction of forest has not been admitted, both in popular belief and by the verdict of science, to have been the cause of misery, of the amount of which the majority even of well-informed persons in England have little conception."

Change the names in this article to those of the hills and mountains of Kentucky, and the process now going on in our State will be startlingly described.

Another result of the reckless clearing up of forests and destruction of timbers is the effect produced upon the climate. I shall have little to say upon this subject, for it lies without the proper sphere of my inquiry. It is a fact, thoroughly proved by experience, that in the far West, as civilization pushes itself backward, clearing up the forests as it goes, the change in climate brought about in a few years is very marked. The winters grow bleaker and colder, the springs later, and the summers drier and more subject to alternations of violent storms and long droughts. The reason for this I believe to be as follows: Heavy forests produce two effects upon cli-

mate in winter—they break the cold, bleak winds that sweep over the country, and give it protection in that way; and they add actual warmth to it from what I believe to be the fact, that the temperature of a living tree never falls quite so low as that of the surrounding atmosphere in exceedingly cold weather. Let the difference be ever so slight, where a country is thickly studded with trees, each one a very little warmer than the atmosphere about it, the effect of the whole upon the climate will be very appreciable. In summer, too, where millions of trees are drawing up water from their deeply-set roots to be evaporated from the leaves, the atmosphere must always be more moist and pure than it would be were it to receive no such water supply to give back in dews at night. This moisture prevents, to some extent, the long droughts to which a country without forests is subject, and, added to the purity of an air washed in fresh dews nightly, tends to prevent the violent storms of wind and lightning which result from a long heated and impure atmosphere. I am well aware that Mr. Meehan, and others equally profound and scholarly, argue that "forests are the result, not the causes of climate," and I am also aware that there are many obvious facts which point, in a certain degree, to that conclusion. Thus, for instance, one might mention the difference between a tropical forest and that of a temperate or frigid climate, or even point to the difference between timbers at different heights, and therefore different temperatures, on the same mountain. Such arguments, however, only go to show that certain timbers are best adapted to certain climates, and that originally there would be no forest at all on a piece of ground not naturally adapted to a forest growth, or that whatever forest did appear, would be the one best adapted to the soil, temperature, and other conditions of growth. But they by no means show, or tend to show, that a given wide range of country would be exactly the same, so far as climate is concerned, whether it were barren or covered with heavy forests. This subject, in its details, however, even were it properly a part of my discussion, is too complicated for further notice, and demands more investigation than I could give to it. A course of long and careful inquiry in this direction, by some able meteorologist and botanist, would be of almost incalculable benefit.

TIMBER IN DETAIL.

I shall now proceed to give in detail an account of the timbers to be found in the counties under discussion, and their local variations. In the immediate vicinity of Princeton the principal timbers noted were bartram oak, white ash, red oak, black oak, swamp white oak, sugar-tree (black), black hickory, white hickory, and liriodendron (yellow poplar). Bartram oak is seldom found, except in low, damp soils, or along streams; but near Princeton considerable quantities appear in a flat woodland quite high and dry. A large per centage of white ash also appears in the same woodland, which lies about one mile from Princeton. With the exception of this woodland, the timbers are mostly cleared away for two or three miles around. The formation is Sub-carboniferous limestone, of Chester Group on high ground, and of St. Louis limestone on low grounds.

In going toward Eddyville, the principal swamp or lowland timbers are, in addition to those given above, yellow birch, pin oak, sweet gum, white and red elm, sycamore, black walnut, and such small growth as flowering dogwood, pith elder, redbud (in small quantities), etc. These alternate with the hill timbers, which are white oak, black oak, scarlet oak, black hickory (scrub), post oak, etc., with some laurel oak, on both low and high grounds, though in the latter case it is always along fence-rows. There is probably 20 or 25 per cent. of white oak among the forest timbers here; but among the bushes and young trees little or no white oak is to be found. The timbers remain essentially the same in all the region of country between Princeton, Eddyville, and Milleville, the swamp timbers being quite good along South Fork and the other small streams in the neighborhood. There is little present drain upon the forests through here, except where the timbers are cut for local saw-mills.

About six miles from Princeton, and not far from the junction of the Hopkinsville and Parkersville roads, a very large spring gushes out from the base of a reddish limestone bluff. Scattered all over this bluff are cedars of various sizes, which I mention as a matter of curiosity rather than of value, as in no other place in this part of Western Kentucky have I seen a member of the coniferous order. A few water poplars (cotton trees) appear along the streams between Princeton and Eddyville, but they are scattering. On the southern slopes of the low hills near Eddyville the white oak is quite good, but not remarkable. Along the Cumberland river, in addition to the timbers already given, hackberry, shag hickory, and honey locust appear. There is quite a marked change in the timbers on the long slopes facing the Cumberland river, near Eddyville. They become very heavy and fine, though the most valuable of them have been cut out. The reason of such change is, that we here pass from the loose rocky or poor shaly limestone of the Chester Group, which is found all along the high ridge road for two or three miles, until the cavernous St. Louis limestone bordering the river is reached.

Another peculiarity noticed in the report in volume II, this series, observation all through this Sub-carboniferous formation confirmed: that is, that the liriodendron (yellow poplar) does not grow on the upper or shaly Chester. If found there at all, it is very scattering, as well as dwarfed, and of no value. The dryness and thinness of the upper Chester soil is doubtless the cause of its absence.

After leaving Eddyville and turning toward Dycusburg, one passes from the St. Louis limestone into the thin Chester of the ridges again. Liriodendron almost wholly disappears, except on streams, and but little white oak is found for some miles. Bartram oak, some hackberry, white walnut (so characteristic of the Ohio river regions), sycamore, white and red elm, etc., are found along the streams; but the forests are not very valuable between Eddyville and Dycusburg. From this statement we may except the post oak, which forms 40 per cent. of the ridge timbers, and which is now used in making hubs for heavy wagons. But I noticed that on these ridges the undergrowth was largely black oak and scarlet oak, which seem to be replacing even the post oak. On the limestone formation along Livingston creek there has once been a considerable amount of liriodendron timber; but that has been cut away, so that scarcely any is now to be found.

In going from Dycusburg back toward the head waters of the Tradewater river, there are some very fine bodies of timber, especially white oak and liriodendron. Along all the small streams and on low grounds, as well as on high grounds in some localities, these timbers are found in great abundance, forming together about 50 per cent. of the forest trees, and are massive and valuable. The liriodendron timber here spoken of, though, does not appear until the cavernous St. Louis limestone, within about four miles of Fredonia, is reached; but from this place to Fredonia there is little variation in size, value, or quality of the timbers. They consist of white oak, black and shag hickory, liriodendron, Spanish oak, black oak, and red oak, with bartram oak, white and red elm, beeches, sugar maple, black gum, sweet gum, and small quantities of honey locust and black walnut at a less height above water level. These timbers remain essentially the same for about three miles beyond Fredonia toward Dalton (formerly Garnettsville), where we pass from the limestone to a coarse, reddish, Sub-carboniferous sandstone, the country becomes quite hilly and broken, and the timbers grow more or less strongly marked into upland and lowland timbers, the two alternating with reference to height above drainage. Even on Sinking Fork of Livingston creek, four miles from Fredonia, no limestone is found. The timbers are the usual swamp ones—swamp white oak, white oak, pig and shag hickory, red and white elm, bartram oak, some white ash, etc. These become very fine about six miles from Fredonia, all along the foot-hills, while the ridges furnish post oak, black oak, scarlet oak, black hickory, and other timbers more or less scrubby. The forest, after leaving Fredonia, cannot be considered very valuable until Donaldson creek is reached,

fully ten miles from Fredonia. There are local spots of valuable timbers, but they are in a hilly, out-of-the-way part of the country, and are not available. The Donaldson creek region cannot be said to be convenient of access, but probably before many years the branches that form its head waters will be penetrated for the old forest walnut that is still scattered along them. These walnut trees vary from twenty to forty inches in diameter—one I noted measuring five feet in diameter, with a straight trunk of sixty feet. But they are largely cut away, even now, to supply local demand. The white oak and less valuable timbers need scarcely be taken into consideration in this locality, as no exigency of the near future is likely to compel a resort to resources so remote from means of transportation. It is enough to say, that along all the streams and branches which go to make up the head waters of Tradewater river white oak, bartram oak, liriodendron (yellow poplar), white and black ash, shag and pig hickory, with more or less white hickory, black walnut, red and white elm, and sweet gum, are found, most of them in great abundance and of the finest kind in size and quality. The hills are covered with post oak, black oak, Spanish oak, and the usual hill timbers.

After turning down Tradewater river from Dalton (erroneously marked on the preliminary map "Chalk Level"), not a great deal need be said in a cursory view of the timbers. The sectional tables, which commence on page 23, will have to be relied upon largely for an accurate knowledge of the nature and distribution of the timbers. The rate at which the forests are now cut away could not be exhibited accurately in tables, but that has already been noticed; so I shall do no more here than to note briefly special points of interest connected with the timbers on the Tradewater river between Dalton and the Ohio.

On Lick creek, a few miles above Dalton, among the finest sweet gums found in Kentucky are noted, varying from two and one half feet to four feet in diameter; shag hickory from three feet to three and one half feet in diameter, white oak three and one half feet, and liriodendron four feet, are also found in great abundance. The formation is a wide and marshy swamp in the coal measures. Black walnut is scarce, and pin oak is large and noticeable immediately on the creek. After crossing Lick creek one enters the splendid "belt" of timbers elsewhere noticed. The ground is high, level, sandy, and moist. The liriodendron and white oak are unsurpassed, and the white, shag, and pig hickories and white ash are of the finest. Bartram oak, which usually grows on low or moist grounds, flourishes. The undergrowth is composed principally of hickory and black oak, of which about equal proportions exist. I have only noticed one other location in Kentucky, of any considerable extent, where the black oak has a rival for the first place among the undergrowth.

On Clear creek a great deal of swamp laurel oak is found, often twenty-six inches in diameter. Near Providence the fine "belt" timber gives out again, one passes from the high, level, sandy soil onto a rolling formation, whose foot-hill timbers are largely white oak, which gives way to post oak, black oak, scarlet oak, and black hickory toward the hill-tops. But little change is noted in the timbers until Crab Orchard creek is crossed. Then one traverses a flat, white, sandy level, where Spanish oak, red oak, post oak, and black hickory form the entire forest. The belt is narrow, and the normal timbers are met with after crossing it. It is worth notice that the western cottonwood is found on Crab Orchard creek, where also the white ash is very fine.

After crossing Crab Orchard creek the road is almost imperceptibly ascending, and one soon reaches the top of a high, level ridge, varying from one to three miles in width, which forms a water-shed that lasts nearly to the Ohio river, with one or two streams cutting across it between Crab Orchard creek and the Ohio. Along the foot-hill exposure of this ridge toward Tradewater the white oak, liriodendron (where it is not cut away), white ash, sweet gum, and other valuable timbers abound. Along the road itself, owing to the naturally high position above drainage, a change of level of a few feet is sufficient to make the white oak give way to post oak and

black oak, or *vice versa*. The white oak is found only in little depressions along the road. After reaching the high hills and deep hollows, upon nearing the Ohio river, the same change of timber with the height above drainage takes place, the only difference being that it takes a much greater change of level to produce a corresponding change in the timbers.

TIMBER TABLES.

The following tables are given consecutively in the order in which they were taken. The area represented by a table varies from twenty-five hundred square yards to five thousand square yards, more or less.

I call a tree decayed where large and prominent branches are dead, or where the body of the tree is not sound, or where it shows general evidences of unsoundness.

Name.	Number.	Average diameter.	Number dead.	Number decayed.
Bartram oak	4	26 inches.	1	1
Red oak	4	23 "	0	1
Black oak	2	26 "	0	1
Swamp white oak	2	18 "	0	0
White ash	7	20–28"	1	1
Sugar maple	2	24 "	0	0
White hickory	2	16 "	0	0
Black hickory	1	26 "	0	0

Location, flat woods near Princeton; formation, St. Louis limestone; undergrowth very scarce.

Name.	Number.	Average diameter.	Dead.	Decayed.
Sugar tree	15	20 inches.	1	3
Scarlet oak	5	19 "	0	1
White hickory	3	small.	0	0
White elm	3	18 "	0	1
Black walnut	3	1–20 "	0	1
Redbud	1	14 "	0	1
Sycamore	3	small.	0	0

Location, a creek swamp four miles from Princeton. Liriodendron trees are in the vicinity, though not in the section.

Name.	Number.	Average diameter.	Cut.	Dead.	Decayed.
Black oak	17	18 inches.	4	0	2
Scarlet oak	2	17 "	0	0	0
Black jack	6	14 "	0	0	1
Post oak	4	16 "	0	0	1
Black hickory	2	14 "	0	0	0

Among the smaller timbers are black gum, flowering dogwood, and pig hickory, with a great deal of upland laurel oak in spots. White oak does not appear in the locality. Location high, level, limestone formation, about seven and one half miles from Eddyville. Cut timber means timber more or less freshly cut; otherwise it would be impossible to classify it.

Name.	Number.	Average diameter.	Cut.	Dead.	Decayed.
White oak	25	23 inches.	8	1	3
Red oak	2	20 "	0	0	0
Black oak	1	18 "	0	0	1
Liriodendron (poplar)	4	18 "	2	0	0
Pig hickory	2	20 "	0	0	0

Dogwood, sassafras, black gum, etc., are small growths. Among the undergrowth black oak and white oak are in the proportion of two to one; while in the old growth it will be noticed their proportion is one to twenty-five. Location, a hill sloping 6° south, situated about five miles from Eddyville.

Name.	Number.	Average diameter.
Black oak	22	16 inches.
Spanish oak	16	12 "
Scarlet oak	7	10 "
Post oak	2	
White oak	1	

Location, about four and one half miles from Eddyville, on Dycusburg road. The forest out so far is nearly altogether second growth, and the character of the timbers is worthy of

notice, as indicating the nature of the forest that will succeed the one now passing away.

Name.	Number.	Average diameter.	Dead.	Decayed.
Post oak	14	17 inches.	0	3
Black oak	6	16 "	1	1
Scarlet oak	7	14 "	0	2
White oak	1	16 "	0	1
Pig hickory	1	14 "	0	0
Black hickory	2	13 "	0	1

Location, a long-rolling, upper Chester formation, about three miles from Dycusburg. Absence of liriodendron (yellow poplar) on the upper Chester is to be noted.

Name.	Number.	Average diameter.	Dead.	Decayed.
White oak	14	28 inches.	2	3
Post oak	2	18 "	0	1
Black hickory	5	20 "	0	1
Pig hickory	1	18 "	0	0
Liriodendron (poplar)	1	28 "	0	0

White elm, black gum, sassafras, etc., are small growth. Black oak forms 50 per cent. of the undergrowth, although it does not appear in the old growth. Location, a foot-hill about three miles from Dycusburg, on the Fredonia road.

Name.	Number.	Average diameter.	Dead.	Decayed.
White oak	15	32 inches.	1	2
Liriodendron (poplar)	9	38 "	0	2
Black oak	3	30 "	0	1
Shag hickory	1	28 "	0	0
Pig hickory	3	26 "	0	0
White ash	1	28 "	0	0

Location, three miles from Fredonia; formation, cavernous, St. Louis limestone, overlaid by a reddish clay. Land very rich. Timber remains heavy on to Fredonia.

Name.	Number.	Average diameter.	Dead.	Decayed.
White oak	13	18–30 inches	0	3
Spanish oak	5	20 "	0	2
Black oak	1	18 "	0	0
Liriodendron (poplar)	2	20 "	0	0
Shag hickory	1	16 "	0	0
Black locust	1	20 "	0	0

Black gum, dogwood, mulberry, and sycamore form the less important timbers.

Location, a foot-hill about three miles from Fredonia, on Dalton road, near a small branch, which forms the dividing line between the limestone and a Sub-carboniferous sandstone. All through to Donaldson creek the timbers are heavy and fine, and a large proportion of white ash is found.

Name.	Number.	Average diameter.	Cut.	Dead.	Decayed.
White oak	17	36–50 inches	6	0	2
Red oak	2	26 "	1	0	0
Liriodendron	5	30 "	2	0	1
White ash	4	18 "	0	0	1
Black hickory . . .	4	20 "	2	0	0
Pig hickory	1	22 "	0	0	0
Sugar-tree	1	20 "	0	0	0

Black walnut, black oak, and white elm are found in the locality. Formation, the sandstone of the coal measures. Location, hill slope, south exposure, just after crossing Lick creek, and on the border of the "belt" of fine timbers spoken of elsewhere.

Name.	Number.	Average diameter.	Cut.	Dead.	Decayed.
White oak	8	26 inches.	1	0	2
Black oak	3	20 "	0	0	0
Pig hickory	6	18 "	1	0	0

Liriodendron is found in the locality, though all the timbers here are below the average in the country. Location, near Providence, after crossing the "belt" of fine timbers.

Name.	Number.	Average diameter.	Cut.	Dead.	Decayed.
White oak	22	23 inches.	6	0	1
Red oak	1	21 "	0	0	0
Pig hickory	6	22 "	0	2	1
Shag hickory	2	21 "	0	0	0
Black gum	4	14 "	0	0	0

Among the undergrowth black oak and white oak are found in the proportion of six to five; but this comparatively large per centage of white oak in the undergrowth is local. Location, a foot-hill about eight miles from Providence.

Name.	Number.	Average diameter.	Cut.	Dead.	Decayed.
White oak	13	28 inches.	5	0	2
Spanish oak	7	23 "	0	0	2
Black oak	1	20 "	0	0	0
Liriodendron	9	21 "	4	0	0
Shag hickory	3	22 "	0	0	1
Pig hickory	2	21 "	0	0	0
White elm	2	18 "	0	0	0
White ash	2	23 "	0	0	1

This is a section of a foot-hill about twelve miles from Caseyville; the following is a section about midway up the same hill, and the last is a section on the hill-top. The three are given to show the gradations of the timbers according to height above drainage:

Name.	Number.	Average diameter.	Cut.	Dead.	Decayed.
Black oak	12	19 inches.	0	0	2
White oak	3	20 "	0	0	0
Spanish oak	5	20 "	0	0	1
Post oak	4	18 "	0	0	1
Black hickory . . .	3	20 "	0	0	0
Pig hickory	1	19 "	0	0	0

Name.	Number.	Average diameter.	Cut.	Dead.	Decayed.
Post oak	15	16 inches.	0	0	4
Black oak	5	17 "	0	0	2
Black hickory . . .	3	15 "	0	0	0

The gradation of white oak into black oak, and black oak into post oak, as leading timbers at different heights above drainage, is well marked. Of the young growth, black oak is the leading timber in all three positions. The hill here given is a good representative of the timbers between this point and the Ohio river.

The numbers given in the foregoing tables include the numbers *cut* also, so that the proportions of sound, decayed, cut and uncut timbers, can be readily seen. Of course, no generalizations from these tables could be relied upon as perfectly accurate; for it is impossible, even with the utmost care, to choose a plot of ground whose timbers are perfectly representative of the locality. Still, the tables were prepared very carefully, and any generalizations made from them can be relied upon as accurate enough for ordinary purposes. By a small amount of computation, a great deal of interesting and important information can be gained from them. I give below a table which shows, at a glance, some of the most important inferences to be drawn from the preceding tables:

Name.	Per cent. uncut.	Per cent. cut.	Per cent. dead.	Per cent. decayed.
White oak	70+	30 nearly.	1.1+	8 +
Liriodendron (poplar)	70	30	Less than one.	10
White ash	99 nearly.	1 +	7 +	14 +
Hickories	94.6 "	5.4+	3.6+	7.2+
Post oak	100 "	Less than one.	Less than one.	24.4 nearly.
Black oak	94.4+	5.5+	1.4 nearly.	14 "
Red oak	88 +	11 +	Less than one.	11 +
Spanish oak	100 "	Less than one.	Less than one.	18.2
Scarlet oak	100 "	Less than one.	Less than one.	14 +

From this table we learn that, so far, at least, as this part of Kentucky is concerned, the hickories are the soundest timbers, and next to them ranks the white oak, while the post oak furnishes the largest per centage of unsound timber. I suspect the reason for this to be, that the post oak is a hill growth almost entirely, and among all timbers there are more decayed branches and unhealthy trunks on high ground than on low ground. This view is partially sustained by the fact,

that although so large a per centage of the post oak timber is decayed, a smaller proportion of it is actually dead than of either hickory or white oak—the two soundest timbers. Few would expect to find the white ash furnishing the largest per centage of dead timbers, but such is the fact. The comparative scarcity of the white ash conceals the relatively large proportion of it that is dying. The most important fact to be noticed in this table, however, is the large amount of white oak and liriodendron that has been cut away within a few years. The loss of thirty per cent. of these two valuable timbers within so short a time, taken in connection with the fact previously noticed, that other timbers are supplanting them as fast as they are destroyed, is alarming. I deem it sufficient merely to call attention to the present rate of loss of the white oak and liriodendron. Any one can realize the calamity which would ensue were they lost altogether to the Kentucky forests.

SUMMARY.

The results of a careful study of the timbers in the counties under discussion may be summarized as follows:

1. The valuable walnut has been, to a great extent, cut out, but some is still found along the heads of the streams that help to form the upper Tradewater river, as well as high up on most streams that flow into it.

2. White oak is found all along the streams and branches of this part of Kentucky, as well as along the foot-hills and on low grounds generally. In many localities, even the hill-tops are covered with it; but, generally speaking, it does not extend high up the hill-sides. The best of that in the immediate vicinity of Tradewater river has been cut and floated out, and the present drain upon the timber is directly proportional to its convenience for transportation. That which is available without much expense will, at the present rate of demand, be exhausted in the not distant future.

3. The ash is not very plenty, and is scattered generally through the forest on rich spots of ground. There is a

good deal of white ash, but it is widely scattered and does not seem so plenty as it really is.

4. The liriodendron, which is so valuable a timber tree, has largely disappeared from the neighborhood of streams capable of floating it out. Even on the smallest streams, local mills are using it up rapidly. I was informed that the forests were once full of it, where now scarcely a tree is to be seen for miles. Great apprehension is to be felt of a want of this timber even in the near future.

5. White elm is found along all the tributaries of the Tradewater, and is tolerably plenty. I had no means of determining its probable proportion in the future forests.

6. Post oak is plenty, covering all the hills through this part of Kentucky, and extending far down toward the foot-hills. There is no need to fear a dearth of it for years to come, though it does not seem to hold its own in the coming forests.

7. No chestnut is to be found in this part of Kentucky. As it exists in great plenty in other parts of the State, on exactly similar geological formations, I could see no reason for its absence.

Complete List of Timbers Found.

ORDER CUPULIFERÆ—MASTWORTS.

1. *Genus Quercus.*
   - White oak, Quercus alba (L.)
   - Red oak, Q. rubra (L.)
   - Pin oak, Q. palustris (Mx.)
   - Spanish oak, Q. falcata (L.)
   - Black oak, Q. tinctoria (Bart.)
   - Post oak, Q. obtusiloba (Mx.)
   - Black jack, Q. nigra (L.)
   - Chestnut oak, Q. castanea (Muhl.)
   - Scarlet oak, Q. coccinea (Wang.)
   - Bartram oak, Q. heterophylla (Mx.)
   - Swamp white oak, Q. bicolor (Willd.)
   - Laurel oak, Q. imbricaria (Mx.)
   - Swamp laurel oak, Q. laurifolia (Mx.)

2. *Genus Fagus.*
   - Common beech, Fagus sylvatica (L.)
   - Red beech, F. ferruginea (Ait.)
3. *Genus Ostrya.*
   - Hop hornbeam or ironwood, Ostrya virginica (Willd.)

ORDER JUGLANDACEÆ—WALNUT.

1. *Genus Juglans.*
   - White walnut, Juglans cinerea (L.)
   - Black walnut, J. nigra (L.)
2. *Genus Carya.*
   - Shagbark hickory, Carya alba (Nutt.)
   - Mockernut, C. tomentosa (Nutt.)
   - Pignut hickory, C. glabra (Sorr.)
   - White hickory, C. microcarpa (Nutt.)

ORDER SILICACEÆ—WILLOWWORTS.

1. *Genus Salix.*
   - Basket osier, Salix riminalis (L.)
   - Green osier, S. petiolaris (Smith.)
2. *Genus Populus.*
   - Cotton tree, Populus angulata (Ait.)
   - Silver-leaf poplar, P. alba (L.)
   - Balm of gilead, P. candicans (Ait.)

ORDER ACERACEÆ.

1. *Genus Acer.*
   - Red maple, Acer rubrum.
   - White maple, A. dasycarpum (Ehrh.)
   - Sugar maple, A. saccharinum (L.)
   - Black sugar maple, A. nigrum (Mx.)
2. *Genus Negundo.*
   - Box elder, Negundo accroides (Moench.)

ORDER ULMACEÆ—ELMWORTS.

1. *Genus Ulmus.*
   - Red elm (slippery elm), Ulmus fulva (L.)
   - White elm, U. americana (L.)
   - Winged elm (Whahoo), U. alata (Mx.)
2. *Genus Celtis.*
   - Hackberry, Celtis occidentalis (L.)

ORDER CORNACEÆ.

1. *Genus Cornus.*
   Flowering dogwood, Cornus florida (L.)
   Low cornel, C. Canadensis (L.)
2. *Genus Nyssa.*
   Black gum, Nyssa multiflora (Wang.)
   Swamp black gum, N. uniflora (Walt.)

ORDER BETULACEÆ—BIRCHWORTS.

1. *Genus Betula.*
   Red birch, Betula nigra (Ait.)
   Yellow birch, B. excelsa (Ait.)
2. *Genus Alnus.*
   Smooth alder, Alnus serrulata (Willd.)

ORDER ROSACEÆ.

1. *Genus Cerasus.*
   Black cherry, Cerasus serotina (D. C.)
   Red cherry, C. pennsylvanica (Ait.)
2. *Genus Cratægus.*
   Hawthorn, Cratægus oxycantha (L.)

ORDER LEGUMINOSÆ.

1. *Genus Gleditschia.*
   Honey locust, Gleditschia triacanthus (L.)
2. *Genus Robinia.*
   Black locust, Robinia pseudacacia (L.)
3. *Genus Cercis.*
   Redbud (Judas tree), Cercis Canadensis (L.)

ORDER OLEACEÆ—OLIVEWORTS.

1. *Genus Fraxinus.*
   White ash, Fraxinus Americana (L.)
   Blue ash, F. quadrangulata (Mx.)
   Black ash, F. sambucifolia (Lam.)

ORDER CAPRIFOLIACEÆ.

1. *Geuus Sambucus.*
   Pith elder, Sambucus Canadensis (L.)
2. *Genus Viburnum.*
   Black haw, Viburnum prunifolium (L.)

ORDER ANACARDIACEÆ—SUMACHS.

1. *Genus Rhus.*
   Smooth sumach, Rhus glabra (L.)
   Large sumach, R. typhina (L.)

ORDER PLATANACEÆ—SYCAMORE.

1. *Genus Platanus.*
   Sycamore, Platanus occidentalis (L.)

ORDER MAGNOLIACEÆ.

1. *Genus Liriodendron.*
   Tulip tree (called yellow poplar), Liriodendron tulipfera (L.)

ORDER LAURACEÆ—LAURELS.

1. *Genus Sassafras.*
   Common sassafras, Sassafras officinale (Nees.)

ORDER ARTOCARPACEÆ.

1. *Genus Morus.*
   Red mulberry, Morus rubra (L.)

ORDER HAMAMELACEÆ.

1. *Genus Liquidambar.*
   Sweet gum, Liquidambar styraciflua (L.)

ORDER SAPINDACEÆ—SOAPWORTS.

1. *Genus Æsculus.*
   Ohio buckeye, Æsculus glabra (Willd.)

ORDER BIGNONACEÆ.

1. *Genus Catalpa.*
   Catalpa, Catalpa bignonioides (Walt.)

ORDER BERBERIDACEÆ.

1. *Genus Berberis.*
   Berberry, Berberis vulgaris (L.)

ORDER ANONACEÆ.

1. *Genus Asimina.*
   Common papaw, Asimina triloba (Dunal.)

ORDER EBENACEÆ.

1. *Genus Dyospyros.*
   Persimmon, Dyospyros Virginiana (L.)

ORDER ERICACEÆ.

1. *Genus Oxydendrum.*
Sorrel tree, Oxydendrum arboreum (D. C.)

ORDER CONIFERÆ.

1. *Genus Juniperus.*
Red cedar, Juniperus Virginiana (L.)

GEOLOGICAL SURVEY OF KENTUCKY.

N. S. SHALER, DIRECTOR.

A GENERAL ACCOUNT

OF THE

GEOLOGY OF A PART OF OHIO COUNTY,

BY CHARLES J. NORWOOD.

PART V. VOL. V. SECOND SERIES.

STEREOTYPED FOR THE SURVEY BY MAJOR, JOHNSTON & BARRETT, YEOMAN PRESS, FRANKFORT, KY.

PRELIMINARY LETTER.

Professor N. S. Shaler, *Director Kentucky Geological Survey:*

Dear Sir: I herewith present the results (that are ready for publication) of my work in Ohio county. It is proper to state, that a number of matters have been left undiscussed, although notes were taken concerning them, as it seemed best that they should be considered in a report dealing with the county considered as a county alone. In this report the county is especially considered with respect to its value in aiding to make clear the history of the western coal field.

The acknowledgments of the Survey are due the citizens of the county generally for their coöperation in furthering the work in their respective regions, but especially are they due Mr. Harrison D. Taylor, Judge Baird, Dr. J. E. Pendleton, Hon. E. Dudley Walker, Mr. J. P. Barrett, and Mr. Carson, of Hartford; Mr. R. B. Thomson, of Elm Lick, and Mr. S. Woodward. Dr. Pendleton, Mr. Carson, and Mr. Woodward presented specimens of archæological value to the Survey; Mr. Taylor and Judge Baird furnished maps, and Mr. Thomson rendered very material assistance to me in a number of ways.

Respectfully,

C. J. NORWOOD.

A GENERAL ACCOUNT OF THE GEOLOGY OF A PART OF OHIO COUNTY.

PREFACE.

The conditions of the beds in Ohio county depend essentially on two nearly parallel disturbances, one of which is an uplift, apparently a synclinal, and traverses the county in an irregular eastwardly and westwardly direction; the other, a disturbance lying within the counties to the south of the Ohio line, near the southern border of the coal field, and which seems to have been, in a large degree, instrumental in shaping the form of the southern limit of the field.

The counties nearest to Ohio county, within which this southwardly disturbance lies, are Butler and Muhlenburg. Accordingly, the southern part of Ohio county, and the northern parts of Butler and Muhlenburg counties, are found to lie within a common geological basin, which is a synclinal one.

North of the Ohio county disturbance the beds seem to have one general sweep—a downward one—towards the north, nearly, if not quite, to the Ohio river. The amount of the depression of the beds, however, varies in that direction; apparently being inconsiderable in the direction of Hawesville, Hancock county, but sufficient in the direction of Owensboro', Daviess county, to bring the upper coals within the hills facing the river, near that city.*

We find, therefore, in Ohio county two distinct geological areas: one occupying the southern half of the county, and forming, with parts of Butler and Muhlenburg counties, a

*It is possible that the very low rocks seen at Hawesville (beds at the base of the coal measures are visible there) may have been brought to light by another disturbance—causing a northwardly rise of the beds. Of this, however, I have no accurate knowledge, and refer to the forthcoming report of Mr. P. N. Moore, on the geology of that region, for the solution of this question.

synclinal basin, which reaches from Rough creek to the southern margin of the coal field; the other, an area with a single slope, and that towards the north. There certainly are local modifications of these conditions; but such seems to be a correct view of the *general* arrangement of the geological features of the regions.

The two regions seem to differ in some special particulars besides the relative positions, towards the surface, of the beds beneath it.

There seem to be indications of a wedging out (so to call it) of some of the beds towards the north, and a lessening in the thickness of some of the coal seams; hence it is not improbable that a larger number of coals are to be found south of the Ohio county disturbance than north of it. This is conjectural, however; and even should it prove true, it does not seem to have been effected by the disturbance—so far as the early history of the coal beds is concerned. This will become apparent further on.

It will be seen that each area has a certain individuality, which serves as a distinguishing feature, and that it is of sufficient importance to render the study of each section, by itself, desirable. Accordingly, the plan has been to limit the study of the geology of these districts less by the geographical than by the geological lines; so that the study of either section should not be confined to a single county, but would include such parts of the other counties as came within the geological bounds. With this in view, and in order that the report may be used in connection with, and properly form a part of, the record of the general results obtained in the study of the synclinal basin, only the southern part of Ohio county—somewhat more than half of the county—is now described.

I.

TOPOGRAPHY.

The topographical features of the district differ little from the general type presented in the interior portions of the western coal field. Soft sandstones and beds of shale of various sorts (usually sandy shale) are the elements from which have resulted a region of much flat land, a few prominent ridges, and occasional conical or flat-topped hills.

The accidents to which the crust has been subjected, viz: the disturbance along Rough creek, with its attendant twisting of the beds, and the uplift at the southern margin of the field, have impressed themselves on the geography of the region in a general way; but the chief features of the topography, so far as relates to details, have been determined by the simple erosion or wearing down of sandstones (usually incoherent) and sandy or clay shales, according to localities. The valley of Muddy creek, of Lewis creek in part, and probably of Rough creek, have been largely determined by dynamical agencies; but the character, both as to course and size, of the larger number of the drainage channels, has depended entirely on the character of the underlying beds and the various degrees of resistance with which they have withstood atmospheric effects. It is not uncommon to find instances where the course of a valley has been altered by the lateral passage of shale into sandstone, or *vice versa*. The effect, on the topography, of the few limestones which occur in the section, seems to have been very limited. In the region about Sulphur Springs, and eastwardly and westwardly from there, along Rough creek, the Sub-carboniferous limestones have given an area of occasional underground drainage, and produced somewhat of the peculiar topography we find when it is based on such beds; but the limestones are so intimately associated with sandstone and sandy shale, that the general features are still very largely those of what may be termed "sandstone topography." The area of the Sub-carboniferous limestones is also quite limited, being confined to a comparatively narrow strip along Rough creek.

The principal streams of the district, besides Rough creek, are Caney creek, Hall's creek, Mill run, Muddy creek, and Walton's creek—all of which are tributaries of Rough creek—Lewis creek, Bull's run, Slate creek, and Indian Camp creek (the head waters)—all of which flow into the Green river.

Chief among these streams are, (1) Caney creek, which flows into the county from Grayson county, and then flows northwardly, approximately parallel with the eastern boundary of the county; (2) Muddy creek, which flows in an irregular westwardly course, and empties into Rough creek about one mile and a half below Hartford, draining the region principally about Elm Lick and Rosine; (3) Lewis creek, which flows westwardly into the Green river, and drains the larger part of the southern portion of the district; and (4) Walton's creek, which drains the larger part of the region about Centretown, and flows northwardly into Rough creek.

The principal ridges of the district are three in number, and are, (*a*) one bordering on Muddy creek, south of the stream, (*b*) one lying farther to the south, whose southern slope is drained by Lewis creek, and (*c*) the "Jerusalem" ridge in the region of Rosine and Elm Lick, which is drained in part by Muddy creek. The general course of these ridges is north of westwardly. There are other ridges, especially north and northeastwardly from Elm Lick and Rosine, which are prominent features in the topography of the region, but their extent is usually short, and their courses quite irregular. The first ridge (*a*), which may be termed the "Muddy Creek ridge," is a low one, for the larger part of its course, and is comparatively short; it seems to coincide with the second ridge (*b*) towards the west, or to fall away and disappear in that direction; it has not been determined which condition occurs. Towards the east it breaks up in a series of rounded hills, which are washed by the numerous small tributaries of Muddy creek.

The second ridge (*b*) may be termed the "Coal ridge," as within it are contained the largest number of important coal beds to be found in any one ridge in the district. This ridge is apparently a part of the main ridge of the coal field, which has been mentioned in a preceding report,* and will be more fully discussed hereafter.

The Jerusalem ridge (*c*) is also an important ridge; but, although it contains a thick and important coal bed, does not

*See part VII, volume IV, Kentucky Geological Reports, N. S. Shaler, Director.

have equal value, so far as concerns coal, with the "Coal ridge."

II.

THE GENERAL STRUCTURE AND COURSE OF THE UPLIFT.

Naturally, one of the most interesting features in the structure of the district is the disturbance which forms its northward limit; hence the discussion of it will serve as a fitting introduction to the general account of the other features of the region. It is a line of uplift which stretches across the county in a somewhat irregular eastwardly and westwardly direction, extending to the Falls of Rough, and perhaps beyond, on the east; and through McLean county as far west as Sebree, in Webster county, and probably beyond.

The existence of the disturbance was discovered by Dr. D. D. Owen; but he does not seem to have recognized its full importance, or to have traced it for any distance, nor to have determined its nature.* He mentions it as the "Barnett's creek disturbance," probably referring to the region about the old salt wells, on Barnett's creek, and does not seem to have traced it any farther towards the east.

The disturbance was for the first time suspected by myself in March, 1874, upon a visit to a point on Rough creek, above Hartford, known as the "Iron Mountain." The discovery of Sub-carboniferous beds there, and the inclination of the strata, proved the existence of some sort of disturbance, but of what kind was not known. Another visit made to the locality in 1875, and the examinations, undertaken along the north and south running railways in the same year, proved the disturbance to have a considerable extent; but it was not until May, 1876, that its true significance and general character became apparent, and it was determined to be a line of uplift. The uplift is probably connected with the disturbance in Union county, described by Dr. Owen, and designated as the "Bald Hill disturbance."† This, however, is entirely conjectural, as

*See page 147, volume I, Kentucky Geological Reports, old series, D. D. Owen, Director.

†See page 112, volume I, Kentucky Geological Reports, old series, D. D. Owen, Director.

that disturbance has not been studied as yet by any officer of the present Survey, nor the westward extension of this one fully determined.

The location of the uplift is distinctly marked in the geography of the region by Rough creek, which, for the larger part of its course, closely follows the line of the disturbance, never permanently leaving it until within a few miles of the mouth of the stream; it does not, in fact, pass entirely beyond the limits of the uplift there. The detailed relations that exist between Rough creek and the disturbance cannot well be determined before the line of the uplift is accurately mapped; but all the evidence collected, so far, seems to indicate the date of the creek valley to be more recent than the disturbance, and that the course of the creek has been considerably influenced by the uplift. Although the disturbance is plainly an uplifting of the beds, and along some parts of its course is plainly an anticlinal fold, its general character, that which is most common throughout its length, is yet somewhat conjectural.

I am inclined to regard the uplift as an anticlinal fold, modified in its general character along some parts of its course. The balance of evidence favors such a classification; but as yet it must necessarily be a provisional one, as at some points the disturbance exists as a *fault*, while at some others the evidence seems to point to a *monoclinal fold*. So far as Ohio county alone is concerned, the disturbance may safely be regarded as (most commonly) an anticlinal fold; but as it extends far beyond the limits of this county, and must hereafter be considered in the relation it bears towards other parts of the coal field, it is desirable to avoid any name that may be too local in its application. Accordingly, from the relations existing between the disturbance and Rough creek, it is designated as the "Rough Creek uplift" in this and a preceding report.*

The course of the uplift varies considerably. The strike of

*See *Report on the Geology of the Regions Adjacent to the North and South Running Railways*, part VII, volume IV, new series, Kentucky Geological Reports, N. S. Shaler, Director.

the beds ranges from north 40° east, in the vicinity of Hartford, to north 85° east (though more commonly north 70° east), in the region about Sulphur Springs and Barrett's Ferry, while west of Hartford the variation is from north 30° west to north 85° west—the strike of the beds at the old salt wells, on Barnett's creek, however, being north 55° west to north 65° west. We thus find an almost complete swinging around of the line of the uplift westwardly from Hartford.

There seems to be little room to doubt, that when the line of the uplift is accurately mapped, it will be found to be marked very faithfully by the course of Rough creek; for that stream seems to depend very largely on the turns of the line of the uplift for its more important changes of direction. The value that the uplift has in directing the course of the stream is curiously illustrated by the decided curve to the south made by the stream when north of Hartford, and the turn then made towards the north just after Hartford is passed. That this is very largely due to the changes in the course of the uplift becomes plain when a map (even a poor one) of the line of uplift is compared with a good map of the stream—which we fortunately have.

From "Clifty Hill," above Barrett's Ferry, to the Sulphur Springs, and a short distance beyond, the general direction of the uplift is about north 70° east; it then changes, and at half a mile south of west of the Sulphur Springs bears north 65° east, and keeps this general course for several miles towards the west. The course is then altered again, and bears north 40° east, at a point northwardly from Hartford.

On the lower Hawesville road, northwestwardly from Hartford, a good view of the tilted beds near the axis of the uplift is obtained; their strike bears about north 85° west. This is modified to north 30° west, still farther west, and is again changed in the vicinity of the old salt wells on Barnett's creek, the strike of the beds there being north 55° west to north 65° west.

It will be seen that the course of the line of the uplift forms somewhat of an open loop near Hartford—the open part of the loop being towards the north. The map of Rough creek shows the same feature in the course of the stream. This loop really represents a shallow synclinal in the vicinity of Hartford, as will be seen from the following: In the immediate vicinity of Hartford, and for some distance north of the town, the beds are found dipping nearly due west, the bearing being a little north of a due west course; but west of the town, on the west side of Rough creek, the dip is reversed, and bears south of east—in some places nearly due southeast—gradually, however, swinging around to the southwest towards Barnett's creek.

The existence of this synclinal may serve to explain the southwardly course of the stream from the mouth of Flat Lick to the mouth of Muddy creek, and its subsequent departure from such close connection with the uplift as exists eastwardly from Hartford. It cannot be said to ever pass entirely beyond the influence of the uplift, for there is a marked relation between the strike of the uplifted beds and the course of the creek, so far as it flows; but its channel is within a different set of beds from those on its upper course (which are the older), and the distance between the stream and the central line of uplift is increased. This seems to be due to the southwardly impetus gained by the stream when turned through the synclinal valley.

Northeastwardly from Hartford the beds, near the central line of uplift, are frequently exposed within short distances of Rough creek. On the Hartford and Sulphur Springs road, Chester limestone, overlaid by about forty feet of shaly sandstone, is exposed in the divide between Hall's creek and Sullenger's branch, about one mile from Hall's creek. Limestone of the same age is exposed in the region about the Sulphur Springs and Hines' Mill. In the vicinity of Sulphur Springs the limestone is frequently found toward the base of the hills, with massive sandstone above it.*

*For the details of the structure of this region, and of all that eastwardly to the Grayson county line, the reader is referred to the forthcoming report of Mr. P. N. Moore on the Eastern Margin of the Coal Field.

Northeastwardly from Sulphur Springs a thin coal bed occurs, in close connection with what seems to be Sub-carboniferous limestone. The coal is about nine inches thick, and is probably at the base of the coal measures. The precise age of the limestone underlying the coal could not well be determined, but it seemed to belong to the Chester Group. The coal is covered by four feet or more of drab sandy shale, and is firm and glossy black. The beds seemed to be dipping at an angle of about 6° course south 25° east. This is on Mr. N. P. Boswell's land.

At Mr. T. J. Barrett's "Sulphur Lick," about two and a half miles north of east from the Sulphur Springs, a sandstone is exposed which is tilted apparently at an angle of nearly 45°. Very little of the bed could be seen, so that the angle of the dip may really not be so steep. Limestone is reported to have been found below the sandstone.

In the Hartford and Hardinsburg road (the old "Louisville and Hopkinsville" road), about half a mile a little south of east from the Sulphur Lick, sandstone, probably equivalent to that seen at the lick, is exposed. The bed is dipping about south 20° east, the strike being north 70° east. Chester limestone is exposed in the road about seventy-five yards northwardly from the sandstone outcrop, but is apparently nearly horizontal. Its place seems to be below the sandstone. *Spirifer increbescens* is very abundant in the rock.

About twenty yards beyond the limestone a thin seam of coal, six to seven inches thick, is exposed, with a dip reversed to that of the sandstone. There seems to be the axis of an anticlinal here. This place is near Barrett's Ferry.

At "Clifty Hill," on the north bank of Rough creek, about half a mile north 65° east above Barrett's Ferry, a fine view of the central structure of the uplift is obtained. Tilted beds of sandstone, shale, and Sub-carboniferous limestone are seen in the following order:

1. Massive limestone.

2. Space; notably sandstone and shale, which are probably crushed.

3. Massive compact sandstone.

The beds are tilted at an angle of 60°, so nearly as could be determined; course about south 20° east. The arrangement of the beds is shown in figure 1, plate I.

Chester limestone, overlaid by sandstone, is also seen in the Hartford and Hardinsburg road, about one mile and three quarters south of west from Barrett's Ferry. The beds at this place seem to be nearly horizontal. Farther to the west, at the crossing of Sulphur run, about one mile and three quarters south 50° east from Sulphur Springs, the Chester beds are again exposed—at the foot of the dividing ridge between Sulphur run and Hall's creek. As the road mounts the ridge rhomboidal blocks of sandstone are exposed, whose place is above the limestone. The beds are nearly horizontal. The lessening in the degree of the dip of the beds is plainly seen as we recede from Rough creek.

In the vicinity of Hartford lower members of the coal measures are exposed, which are affected by the dip of the Subcarboniferous beds to the north, but show a change in the direction of dip, as compared with that seen towards Sulphur Springs. At the "Foreman Riffle," on Rough creek, about half a mile above Hartford, shaly sandstone is exposed—the beds dipping apparently south 45° west. The precise direction is obscure, as the outcrop is limited.

At the "water" mill, at Hartford, higher beds are seen, consisting of sandstone, limestone, and coal, which have a considerable dip nearly due west. At the mill the inclination of the beds amounts to eight feet in one hundred and eighty feet. On the Hartford and Hawesville road, about five miles west of north from Hartford, Chester beds, consisting of sandstone, limestone, and shale, are exposed, inclined at a steep angle. At one place the sandstone shows a dip of 28°, course south 60° west; this, however, seems to be a local exaggeration, as the more trustworthy beds of limestone show a dip of only 15°, course south 25° west, which is probably the general inclination of the beds in the locality.

On Barnett's creek, on Mr. Lewis Turner's land, and in Mr. Stephen Woodward's field, near the "old salt wells," Sub-carboniferous limestones are exposed tilted at high angles.* On Mr. Turner's land the limestone, thirty feet of which is exposed, is inclined at an angle of 40°, course south 35° west. This place is about three and a half miles, by map measurement, above the mouth of Barnett's creek.

Such are the features to be observed in a general survey of the Rough creek uplift. The disturbance is certainly one of the most interesting problems to be found in the western coal field, not only in its scientific but economic bearings, and merits a more extended study than it has yet received.

III.

THE GENERAL STRUCTURE OF THE DISTRICT.

As intimated on a preceding page, the principal topographical features of the district south of the Rough creek uplift are a principal ridge, having a northwestwardly trend, which forms the water-shed for the waters of Lewis creek on the south, and the waters of Muddy creek in part, and of Rough creek in part, on the north, and a subordinate ridge to the north and south of the principal one; this is the "Coal" ridge. These, with the "Jerusalem" ridge, are the principal features; but they are not the only prominent ones. The "Ben's Lick hills," between Brush creek and Ben's Lick creek (both of which streams flow into Rough creek); a few conical hills on the borders of Muddy creek; the ridge down which flow the streams of Flat Lick, Mill Run, etc. (but which is very much broken, and is really connected with the ridge northwardly from Rosine), and the ridge at Point Pleasant and near Centretown, are also prominent, especially in their geological value.

The coal ridge, which, for the larger part of its course, lies south of the railroad, and extends in an irregular line from the head waters of Indian Camp creek to the Green river,

*This is probably the locality visited by Dr Owen; see page 147, volume I, old series, Kentucky Geological Reports, D. D. Owen, Director.

with its various spurs, seems to contain not only a larger number of coals, but a larger area of thick beds than any of the other ridges.

The Ben's Lick hills contain some of the thick beds; the Jerusalem ridge contains a bed from three feet ten inches to six feet six inches thick (including a clay parting), and within the ridge near Centretown, and at Point Pleasant, the thickest bed of coal in the district is found; but compared with that of the beds in the coal ridge, the area of the coals is small. The precise value, in beds of coal, of the coal ridge, cannot be determined until its form is accurately mapped.

The general slope of the beds from the Rough creek uplift is, east of Hartford, between 20° and 35° east of south; west of Hartford the direction, as indicated on a preceding page, is very variable, the general course, however, being southwestwardly. East of Hartford, the southwardly slope of the beds seems to terminate at the valley of Muddy creek, giving place thereat to a southwardly rise.

The region west of Hartford has not been studied sufficiently in detail for the precise limits of the various dips of the beds to be determined. The dip is not only very variable, but complicated by a small fault, which extends northwardly from Rockport, on the Green river. It may be said, however, that, in that region, there is a general retreat, to the northward, of the limit of the southward slope of the beds as the Green river is approached; that is, the line limiting the southward slope swings round west of Hartford and points towards the northwest, in the direction of the Green river.

It seems that, were these lines projected on a map, they would be found to represent an imperfectly formed letter V —one stem reaching out past Beaver Dam, Elm Lick, and Rosine, and the other one extending towards Point Pleasant, on the Green river—the angle being somewhere between McHenry and the Lewis creek tunnel.

South of these lines the strata rise towards the south. It will therefore be seen, that the larger part of the valley of Muddy creek is within a synclinal depression, the direction of

which is northeastwardly. It seems, indeed, that the "Muddy Creek" ridge, at the base of which Beaver Dam stands, may be regarded as a synclinal one. It seems to be near the central axis of the great synclinal (so to call it) extending from the Rough Creek uplift to the southern border of the coal field.

NUMBER OF COAL BEDS AND THE GENERAL SECTION.

There seem to be at least eleven distinct coals within the district; but only ten have been fully identified. This does not take into account the coals towards the extreme eastern margin of the county, in which direction there is at least one bed lower than the ones enumerated in the following section, nor yet those lying closely along the uplift. So far, I have been unable to satisfactorily obtain the direct connection between these lowest coals and the ones lying above them, on account of the limited character of their outcrops, and the difficulty of tracing the strata—a difficulty which will be recognized by one who has worked in this coal field, where the beds are seldom horizontal for any considerable number of miles, and the structure is so frequently masked by disintegration of the rocks. I have accordingly preferred to limit the section more particularly to those localities where the element of dip would have the least bearing in the computation of the distances between the beds; where, indeed, the direct connection of one bed with another one could frequently be obtained, by simply descending from the one bed to the other, without passing over any considerable horizontal distance. In the region bordering immediately on the lower uplifted rocks, the dip, as mentioned on a preceding page, is quite variable, both in amount and direction. Farther to the south, however, where the slope of the beds is towards the north, the dip is more regular in amount, and more constant in direction; consequently, the relations between the beds are generally quite plain. In several instances, vertical sections of the ridges have shown as many as four coals in orderly succession, while many of the sections show from two to three coals following one another within short horizontal distances. The grouping of these sections, by the identification of some of the members of one section with corresponding ones of another, has resulted in establishing a general section showing a thickness between five hundred and six hundred feet of beds —including at least ten comparatively constant coals and one whose character is yet conjectural.

Even those coals that may be regarded as comparatively constant are not, however, presumed to be present everywhere that their horizons are reached. There seem to be at least two whose places are sometimes filled with sandstone or beds of shale; and the indications seem to be, that in the vicinity of Fordsville (which, however, is north of the northern limit of the synclinal basin) there is a shortening from the base upwards of the section, and an absence of some of the coal beds. Whether this is actually the case, however, is as yet problematical; and should it prove to be the case, the cause is as yet imperfectly understood. There is this to be said, however, in such a connection: at Fordsville, and on the extreme eastern margin of the district, the coal-bearing series rest immediately on the Chester Sub-carboniferous) beds. At Fordsville, and near the Sulphur Springs, a thin seam of coal, which may possibly be Coal L, rests within a few feet (sometimes within a few inches) of the Sub-carboniferous limestone.* This is to be observed at Spring Lick, in Grayson county, and further east. At Spring Lick, Coal L occurs at five feet above the Chester limestone.†

Towards the southern border of the field, in Butler and Muhlenburg counties, a conglomerated sandstone, known simply as the "Conglomerate," lies at the base of the coal measures, and is interposed between the lowest coal and the Sub-carboniferous beds. The same conditions as those to which the Conglomerate owes its presence on the south, while it is absent towards the east and on the northern limits of the

* For a full discussion of the section at Fordsville and surrounding region, see the forthcoming report of Mr. P. N. Moore, hitherto mentioned.

†See page 54, part VI, volume I, Kentucky Geological Reports, new series, N. S. Shaler, Director.

synclinal basin, may have been of value in determining the distribution of the coal beds.* This is to be regarded merely as a suggestion.†

All things being considered, the evidence as to the apparent shortening up of the section, and the decrease in the number of coal beds in the direction of Fordsville, is of a nature too imperfect for the basing of any conclusion upon it. Any absence of beds that should be proved to occur in that direction might be due to such local accidents, comparatively limited in their operations, as are known to have occurred in connection with some of the beds in the more central part of the coal field.

Such suggestions as have been made in regard to the shortening up of the section, or diminution in the number of coal beds, are not, therefore, to be regarded as conclusions based on well-worked out facts, but as suggestions of the conditions possibly existing. It is only when the region is worked out carefully in detail that the problem will find its solution.

The following is a general statement of the beds in the synclinal basin;‡ it is a generalization of about forty local sections, besides the more general observations:

GENERAL SECTION.

No.	Description of Strata.	Feet.	Inches.
1	Sandstone, the "Anvil Rock."		
2	Shale.		
3	*Coal A*	5	
4	Shale	. . .	6
5	Limestone	1	6
6	Shale . . . 0 to	2	
7	*Coal B*	6	
8	Under clay	2	
9	Sandstone {This space is sometimes filled with a single massive sandstone.}	25	
10	*Coal;* not always present (C?)	. . .	3
11	Sandy Shale and Sandstone	30	
12	Bluish Shale, with ochre concretions	25	
	Carried forward	97	3

*This question is probably discussed in the Biennial Report of the Director of the Survey.

†Some fragments of Conglomerate have been found near the line of the Rough Creek uplift, but have not yet been traced to a bed *in situ*.

‡The regions about Centretown and to the west, and that about Point Pleasant, are excepted, for reasons which are given on another page.

GENERAL SECTION—Continued.

No.	Description of Strata.	Feet.	Inches.
	Brought forward	97	3
13	Bituminous Slate . . . 2 feet to	4	
14	Pyritous band filled with fossils; not always, though usually, present	. . .	2
15	*Coal D* . . . 5 feet 7 inches to	4	8
16	Under clay; frequently contains an irregular bed of concretionary masses of light blue, smooth-grained limestone	3	
17	Sandstone and shale . . . 45 feet to	50	
18	Bituminous Slate containing fish scales . . . 3 feet to	5	
19	*Coal E;* sometimes divided into several members . . . 16 inches to	1	6
20	Space; notably shale	17	
21	Grey Limestone; may not be precisely in place	2	
22	Space; notably sandstone and shale	10	
23	Black Slate, filled with fish remains . . . 18 inches to	3	
24	*Coal E^a^* . . . 14 inches to	1	8
25	Under clay	3	
26	Soft disintegrating Sandstone. This is frequently a mixture of shaly disintegrating sandstone and sandy shales {This space is sometimes increased to 40 feet, and filled with soft sandst'e.}	27	
27	Space; sometimes filled with reddish clay {This space is sometimes increased to 40 feet, and filled with soft sandst'e.}	5	
28	Bituminous Slate . . . 0 to	1	6
29	*Coal F* . . . 9 inches to	1	6
30	Under clay . . . 0 to	3	
31	Mottled dark drab and ashy-grey or white, impure Limestone. Has frequently a brecciated appearance on the surface, and is sometimes somewhat nodular on top. Weathers a brown or ferruginous tinge. Contains *Spirifer* (*Martinia?*) *lineatus*, *Martinia plano convexus*, and *Rhombopora lepidodendroides* . . . 1 foot to	2	2
32	Shale	20	
33	Sandstone and shale {This space is sometimes filled with a massive sandstone 65 feet thick.} 20 feet to	35	
34	*Coal G* {This space is sometimes filled with a massive sandstone 65 feet thick.}	1	2
35	Sandstone and shale {This space is sometimes filled with a massive sandstone 65 feet thick.}	30	
36	Blue, shelly earthy Limestone. In places has somewhat of a concretionary structure near the middle of the bed. Breaks with an irregular fracture. Organic remains are abundant, including *Productus muricatus, Prod. Pratteniatus, Prod. Nebrascensis? Spirifer cameratus, Athyris Subtilita, Aviculopecten* ——? *Chonetes mesoloba*, etc.	6	
37	Dark calcareous Shale, containing numerous small calcareous concretions; merges above into No. 36, and below into No. 38. Contains *Productus muricatus* and *Chonetes mesoloba* in the lower part	7	6
38	Impure, coarse-grained, dark grey crinoidal Limestone	. . .	
39	Argillo-calcareous material. Somewhat of a shale. Is filled with *Productus muricatus*, especially at the bottom	1	
40	Black Shale interlaminated with thin streaks of coal	. . .	1½
41	*Coal* . . . 11 inches to	1	6
42	Under clay. This is dark grey and very impure, specks of charcoal and small concretions of pyrites being abundant in it. Base not seen	1	
43	Space, mostly filled with argillo-sandy shale	7	
44	Hard Chert, usually in rhomboidal blocks Color, yellow and dark. Usually abounds in *Fusulina cylindrica*, and may be identified as the "*Fusulina Chert*"	. . .	6
45	Shaly Sandstone, or argillo-sandy shale . . . 10 feet to	20	
46	*Coal* . . . 16 inches to	2	7½
	Carried forward	376	8

GENERAL SECTION—Continued.

No.	Description of Strata.	Feet.	Inches.
	Brought forward	376	8
47	Space; mostly Sandstone {This space varies from 40 to 70? feet, and is sometimes nearly all sandstone.}	30	
48	Argillaceous Shale {This space varies from 40 to 70? feet, and is sometimes nearly all sandstone.}	10	
49	The "*Elm Lick Coal*" divided by a clay parting thus: *a.* Coal . . . 18 inches. *b.* Clay . . . 4 to 18 " *c.* Coal . . . 36 "	6	
50	Space	5	
51	Massive Sandstone	35	
52	Shale	5	
53	*Coal* . . . 22 inches to	2?	
54	Space	46	
55	Sandstone and shale	7	
56	Sandstone, soft and disintegrating	12	
	Total	534	8

It will be seen in the above statement, that the distances are sometimes considerably modified. The observations have not been sufficient to determine the most common distances between such beds, nor the character of the materials most generally filling the spaces. This is especially true of the spaces between the limestones No. 31 and No. 36, and between the Fusulina chert and the coal No. 49.

In the vicinity of Cromwell (as at Greenville, in Muhlenburg county), a coal bed of fourteen inches in thickness (No. 34 of the section) occurs at fifty-five feet below the "mottled limestone," No. 31—the space between being filled with shaly sandstone and shale. In the neighborhood of Mr. L. D. Taylor's, however, the section is shortened, the coal No. 45 being only one hundred feet below the mottled limestone, the probabilities being that coal No. 34 is not present. Near Mr. James Raley's the coal No. 34 is evidently not present, as a massive sandstone sixty-five feet thick occurs at twenty feet below the limestone; the sandstone also appears either to cut out the beds from No. 35 to No. 44, or to considerably lengthen the section. This is shown on plate 2.

The space between the Fusulina chert (No. 44) and the Elm Lick coal is also variable, and the standard distance has not been fully determined. Barometrical measurements* have been made, which seem to show a variation in the distance from about fifty to seventy feet. The amount of variation seems to depend on the thickening or thinning of a soft massive sandstone, which underlies the first coal below the chert. The sandstone seems to vary in thickness from thirty to fifty feet, and thus causes the distance between the two coals to range from about thirty-five to fifty feet. It is not improbable that this sandstone cuts out the coal occasionally; of this, however, the evidence is not satisfactory.

The space between the Fusulina chert and the first coal below it (No. 46) varies comparatively little. It is probable that the coal will very generally be found at about twenty feet below the chert.

It will be seen that the lower part of the section undergoes considerable changes in the several parts of the district; accordingly, the record from bed No. 34 to bed No. 53 must be regarded as somewhat preliminary in character, until sufficient data have been obtained to warrant a final revision of the statement, and a determination thereby of the standard distances between the coal beds.† The expediency of this will become apparent hereafter.

From coal A (No. 3) downwards to coal F, however, the distances given in the general section seem to be comparatively constant; accordingly, that part of the section may be considered as generally applicable over the district.

It may also be well to state, that Coal G is, so far as at present known, more frequently found than not, at about forty feet below Coal F.

DESCRIPTION OF THE BEDS.

The larger number of the prominent beds of the section are so fully marked by their individual characters, that their identification is easy; some of them, however, are to be identified only by the beds found associated with them.

* These are without correction, as I was without facilities for checking them.

† This work is now in hand.

The "Anvil Rock" Sandstone.—As is mentioned in a former report* (in which it is fully described), this sandstone received its name from Dr. D. D. Owen. It is to be identified only by its relative position towards other beds. So far as relates to this county alone, there is little to be added to the descriptions of the rock which have already been published. Observations which have been made in Muhlenburg county, however, tend to prove the accuracy of the suggestions formerly made as to the probability of the sandstone being conglomerated in some localities.†

Coal A.—This bed is very seldom wrought in the county, as its extent, as a workable bed, is limited to small areas. Unless it is in the region about Point Pleasant and Centretown, the deposit seldom reaches any considerable thickness. This, in a large measure, is due to the high position it occupies in the section, which usually brings it so near the tops of the hills that the coal wastes away under the action of the weather. The place of the bed is frequently only indicated by a dark earth or by its stained "under clay."

The inconstancy of Coal A has been pointed out in a former report,‡ and was referred, in part, to the varying conditions which no doubt existed during the deposition of the Anvil Rock sandstone; but the examinations in this district have seemed to show, at some points, the absence of Coal B when Coal A was present. This, however, is not fully proven, as in every case where such conditions seemed to exist the section was not fairly exposed.

Coal B.—This bed has been fully described in a preceding report.

It is probable that in the region about Hamilton, McHenry, and Rockport, the coal may be found in a workable condition. It is worked at Paine's mines, on the river, opposite Rockport, and at Airdrie, farther up the river. The bed is not found east of Beaver Dam, and its place in the ridge south of that

* See part VI, volume I, new series, Kentucky Geological Reports, N. S. Shaler, Director.

† See part VII, volume IV, new series, Kentucky Geological Reports, N. S. Shaler, Director.

‡ Part VI, volume I, new series, Kentucky Geological Reports, N. S. Shaler, Director.

place is only indicated by a black "dirt." Much that has been said concerning Coal A may be applied to Coal B in this district.

Coal D.—This bed has also been described sufficiently well in a former report. Since the publication of that report, however, the coal has been found showing a larger thickness than was reported therein.

On Mr. Alfred Brown's land, one mile and a quarter about south 10° east from Beaver Dam, the coal has been opened, showing a thickness of five feet seven and three fourths inches. The usual thickness of the bed is four feet eight inches. The coal is covered by a slabby bituminous slate, which frequently contains large pyritiferous concretions, and this is usually overlaid by bluish argillo-sandy shale, containing ochreous concretions. In some places, however, the slate is immediately overlaid by a massive sandstone, fifty to seventy feet thick, as at the old Taylor mine on the Green river, below Cromwell.

Coal D seems to be the most trustworthy coal in the district, but its area is irregular in form. So far, the observations seem to prove the bed to be confined to the region south of Rough creek. Its eastern limit would be marked by an irregular line drawn from near the mouth of Ben's Lick run, on Rough creek, in a southeastwardly course to Kate's Hill, on the Hartford and Morgantown road, southeastwardly from Beaver Dam; thence it extends, with a westwardly curve, to the old Taylor mines, on the Green river, passing west of Cromwell and Pinchico. There are probably some exposures of the coal east of this line in the southern part of the county, but they are quite detached, and occupy comparatively small areas, although some of them may doubtlessly be extensive enough to supply a mining company for years with coal. The line indicated undoubtedly marks the eastern limit of the coal as a solid sheet.

South of Lewis creek, the beds sink towards the west, so that Coal D may be regarded as underlying the larger part of the region included between the Green river and the imagin-

ary line to the east, except that part towards Rochester. In the vicinity of Rochester lower coals are the first ones beneath the surface.

North of Lewis creek Coal D does not seem to have so wide an area, at least not as a continuous sheet. It seems to underlie only a somewhat triangular area in the region between Clear run and Ben's Lick run, known as the "Ben's Lick Hills," reaching not quite to Clear run; and then to be absent for a considerable distance to the west, on account of both the geological and topographical conditions.*

In the region to the west the position of the coal is affected by the small fault which courses northwardly from Rockport. The coal, under other conditions, has a northwestwardly rise from Miller's bank (in the Ben's Lick Hills); but the Rockport fracture† having occurred since(?) the beds were raised in that direction, the coal has been let down about fifty or sixty feet towards the west along that line of fracture, and towards the Green river the direction of the rise of the beds is changed to about north 40° east. In consequence of these conditions, Coal D seems to be deep-seated in the region between Rockport and Point Pleasant.

Coal E.—This coal has been the source of some confusion, not only to myself, but to the officers of the first Survey. There is no doubt that this bed, and the one lying immediately below it, were confounded with each other—their slates being so nearly alike, and the distances between them so short—and the two referred to a single bed. The investigations of the past season prove the existence, beyond a doubt, of two beds instead of one, one of which, without doubt, corresponds to Coal E of the nomenclature adopted in the preliminary work of the present Survey, or No. 8, according to the numbering used by Dr. Owen. The other bed may, for the present, be designated as Coal E^a.

*In volume III, page 543, of the first series of Kentucky Geological Reports, a coal, which is exposed in the left bank of Rough creek, at Hartford, was identified as Coal D ("No. 9"). But, as shown in a former report, that coal is a lower bed. Coal D, as shown on a succeeding page, is worked in the Ben's Lick Hills, and is plainly above the bed seen at Hartford, even measuring the height by its topographical position alone.

†Described on a succeeding page.

In the report on the geology of the region adjacent to the Louisville, Paducah and Southwestern Railroad, the conclusion is given that Coal E is very untrustworthy. This statement was, of course, based on the impression that only one bed occurs in the space in which two are now known to lie, and which were confounded with each other. The more recent observations have shown the possible necessity of modifying the statement as to the constancy of the bed; but there is no reason to question the accuracy of the conclusions as to the general thickness, and the value of the coal for industrial purposes. It has nowhere been found sufficiently thick to be mined with profit.

The coal is usually overlaid by a thick deposit of dense, black bituminous slate, which breaks into slabs, and in which a few fish scales and spines(?) are found. The fish scales are peculiar in form, but alone do not serve to identify the slate, as the slate covering the lower coal is much more abundantly filled with them. For a perfect identification of the bed, in a case where one is unacquainted with those peculiar characters that may be observed in a certain coal, but not described, and are to be known only through practical experience with the bed, it is necessary either for the whole or a large part of the coal and its roof of slate to be exposed, or for some one of the coals associated with it to be exposed in the vicinity. The distance from the base of Coal D to the top of Coal E is from forty-five to fifty feet.

The following is a section of the bed as exposed on Mr. Poyner's land, southeastwardly from Beaver Dam; it may serve as an example of the conditions usually presented by the coal in this district:

No.	Description of Strata.	Feet.	Inches.
1	Black, hard, slabby bituminous slate	3	
2	Drab clay, rather hard	...	5½
3	Coal and clay } 14 inches ... 1 inch to	...	1½
4	Clay } 14 inches ... ½ inch to	...	1
5	Coal, base not seen. } 14 inches ... said to be 1 foot to	1	2

The most trustworthy features to be observed in connection with this coal, and to be used as means for its identification, seem to be the extraordinary thickness of the black slate overlying it, the thickness of which sometimes measures five feet, the occurrence of the peculiar fish scales and spines(?) in the slate, and the clay divisions in the coal. The fish remains seem to be peculiar to the slates over Coals E and E^a, being, however, more numerous in the slate over the lower coal, which slate is also to be distinguished from the one overlying Coal E by its being less dense, and usually not more than half so thick.

Coal E extends over a wide territory. It lies near the surface east of Beaver Dam, in the region about Liberty Church, near Hartford, Cromwell, and Pinchico, and may safely be presumed to underlie all that area in which Coal D is present.

Coal E^a.—This bed normally occurs at twenty-five to thirty feet below Coal E. It is probably the one most often mentioned as Coal 8 in the reports of the first Geological Survey (although there is no doubt that the upper bed was also identified with that number), and is the one generally regarded as Coal E in the report on the coals along the line of the Louisville, Paducah and Southwestern Railroad.*

On account of reasons which it is now unnecessary to enumerate, the identity of this coal, as distinguished from the one now designated as Coal E, was not discovered when the region was examined for the first time.

The coal varies from fourteen inches to twenty inches in thickness, and is covered by two feet of usually hard, frequently polished, bituminous slate, abundantly filled with fish scales and spines(?). An occasional fish tooth, *Peripristis semi-circularis*, is also found in the slate; but teeth are rare. The slate is not always hard nor polished, but is sometimes dull black and quite fragile. The character and fossil contents of the slate serve as very fair means for identifying the coal.

*This bed was also identified as No. 7 at some places by officers of the former Geological Survey.

Coal E[a] probably has an area equal to that of Coal E, if not a larger one. It should be stated, however, that neither bed is frequently exposed in the county; other beds concealing them, or the topographical conditions being unfavorable.

Coal F.—When this district was first traversed this bed was not observed, the space seeming to be completely filled with sandstones and shales. The more general examinations made during the past season have proved the presence of the coal over a large part of the district.

The thickness of the coal varies considerably, ranging from nine inches to eighteen inches; but its horizon is well marked, and it may be identified wherever the topographical conditions and the positions of the beds are favorable.

As a surface bed, it is most frequently exposed in the region near Cromwell and about Liberty Church, its outcrops seeming to be chiefly limited to the ridge forming the water-shed for the waters of Lewis creek, Indian Camp creek, Slaty creek, and Muddy creek.

The place of the coal is marked by a peculiarly mottled drab-colored and ashy-white limestone, varying in thickness from twelve inches to twenty-six inches, which is described as No. 31 in the general section. This bed is the equivalent of the mottled limestone seen at Greenville, and probably of the upper "impure limestone" indicated in the Airdrie section, as given by Dr. Owen.* Its identification in this district proves the extent of the bed to be greater than was suggested in my former report.

Coal G?—This bed was also observed for the first time, in this district, during the last summer (1876). It was formerly presumed not to be present far beyond the Green river, in an easterly direction. Its precise character is still conjectural, as the bed was observed at only one place in the county, near Cromwell, and was then seen only as a coal "dirt." The general extent of the coal is accordingly unknown, but the bed

*See page 25, volume III, Kentucky Geological Reports, old series, D. D. Owen, Director.

seems to be irregular in extent, or, at least, to be interrupted by sandstone at some places.

Number 36—Limestone.—The principal outcrops of this limestone are in the region bordering Rough creek. As stated on a preceding page, it seems to be cut out, and its place filled with sandstones and shales, in some parts of the district; it is so earthy in composition, however, and disintegrates so readily upon exposure, that, in some cases, the limestone is probably merely concealed by débris, chiefly the result of its own disintegration, instead of being absent. In some places it seems to be represented only by a cellular, apparently somewhat silicious, yellow limestone, or calcareous mass, abundantly filled with *Productus muricatus*, which is immediately underlaid by the coal No. 41 of the section.*

Number 41—Coal.—This bed has been observed at but few places, its horizon usually being covered. It is exposed at the water's edge at the water-mill at Hartford (where its thickness is eleven inches); on the Hartford and Morgantown road, by the former residence of Col. O. P. Johnston (now owned by Mr. Williams), and on the land of Mr. J. B. Bennett, on the Hartford and Livermore road. Little more is known concerning the coal. It is possible that it may prove to be a bed of some value when more fully studied.

Number 44—The "Fusulina Chert."—This bed, or rather the débris of it, is more frequently found than the blue shelly limestone, which occurs above it. It seems probable that, in some places, it is present and the limestone not; but this has not been proved.

The chert is easily recognized by the large number of *Fusulinæ* contained in it. The chert was seldom found in a compact bed, hence its general thickness was not determined; in a few places it measures six inches. Few fossils, other than the *Fusulinæ*, were found in it.

Number 46—Coal.—This coal seems to be fully as persistent as any of the beds below Coal D. It has never been

*A fuller account of this limestone, and its general relations, which are important, will be given in another report.

found fairly exposed, its place usually being indicated by a stain or a "dirt." At one place, however (at Mr. L. D. Taylor's), the bed has been opened sufficiently to expose a hard, good-looking coal thirty-one and a half inches thick. In some localities the bed seems to have a clay parting.

It has been found on the Hartford and Morgantown road, near Col. O. P. Johnston's former residence, where its outcrop measured eighteen inches; at Mr. L. D. Taylor's, as mentioned above; on Dr. Berry's land, on the Morgantown road, about three miles and a half from Hartford, and on the William Hines tract of land, now owned by Messrs. Walker and Berry, about four miles and a half or five miles about south 80° east from Hartford. The place of the coal is indicated by the presence of the Fusulina chert at a number of other points in the district, viz: on the old Nall tract of land, now owned by Hon. E. D. Walker, two and three quarters miles about north 70° east from Hartford, by the spring near the house; on land belonging to the heirs of Mr. Richard Stephens (deceased), on the Morgantown road, three miles from Hartford; on Mr. Spangler's old place, near Beaver Dam, towards Elm Lick; in Mrs. Barnett's lane, about one mile westwardly from Hartford, etc.

Number 49—*The Elm Lick Coal.*—This coal is one of the most important beds in the district. It is the one which has been wrought at the Martin bank, about one mile westwardly from Elm Lick; at Mr. Otto's and Mr. Chiles' banks, near Rosine; the one which is now wrought occasionally at the bank on Hon. E. D. Walker's land, known as the "Hines bank," and at banks belonging to Mr. Henry Thomson and Mr. George Neighbors, in the region south of Elm Lick. It may be the coal opened on Mrs. Charlotte Barnett's land, near the Hartford and Owensboro' road, about three miles from Hartford; this, however, is conjectural, as the bed wrought there was not exposed at any time when the place was visited, and the descriptions given concerning it vary.

The coal seems to be, very generally, what is known among miners as a "split vein." It is parted into two members by

a clay seam, varying in thickness from three inches to eighteen inches. It may not be the rule, but, so far as observed, the thickness of the clay parting increases from the north towards the south. At the "Hines bank" it measures four inches, at the Martin bank six to nine inches, at the Chiles bank seventeen and one fourth inches, and at the opening on Mr. Henry Thomson's land the clay is from twelve to eighteen inches thick.

Following are sections of the bed which illustrate its general features in regard to thickness:

Name of bank.	Hines bank.		Martin bank.		Chiles' bank.		Thomson's bank.	
Thickness.	Feet.	Inches	Feet.	Inches	Feet.	Inches	Feet.	Inches
Upper member	1	. . .	1	6	1	9	1	5
Clay	. . .	4	. . .	6	1	5¼	1	6
Lower member	2	6	3	2	?	. . .	3	5
Total thickness	3	10	5	2	?	. . .	6	4

The upper member is usually poor, frequently being quite pyritiferous. As an average, it contains about 2 per cent. of sulphur. The lower member is very fair coal, though rather soft, and contains, as an average, about 1.8 per cent. of sulphur.

This bed will probably prove to be one of the most profitable coal deposits in the district.

Number 53—*Coal.*—Very little is known concerning the character and general extent of this bed. It was identified only at Mr. Jesse B. Mosely's, two miles and three quarters southwardly from Elm Lick; at Mr. L. L. Taylor's(?), half a mile eastwardly from Mr. Mosely's, and at Mr. Black's spring(?), about one mile and a half about northwest from Elm Lick.

A coal was seen at Mr. James Stewart's spring, about one mile nearly due south from Thomson's bank, which may prove to be the equivalent of this bed. It has a clay parting, and measures as follows:

a. Coal	12	inches.
b. Clay	2½	"
c. Coal	6	"
Total thickness	20½	"

At the time the locality was examined, it was thought that this bed (at Stewart's) was probably the southern extension of the one seen at Mr. Thomson's. But for this to be true, there must be either a local dip of the bed to the south in that region, amounting to thirty feet in the mile (provided the measurements for vertical distance are correct*), or a fracture, extending eastwardly and westwardly, south of the Thomson bank—allowing the beds to drop a distance of thirty feet south of that line; neither of which conditions is clearly indicated.

As stated on a preceding page, that part of the general section included between No. 34 and No. 53 is to be considered as, in a certain degree, preliminary to the general summing up of the facts concerning the whole basin, and, for the present, it serves rather as a basis to work from than as a fully determined conclusion. Accordingly, the relations existing between certain of the beds are given as they are now understood, but with the provision that it may become necessary to revise some of the present conclusions.†

There are some beds of coal which may not be represented in the section, as the conditions surrounding them were such that, although, as at Mr. C. W. Stephens', one of the coals was easily identified with another well-known bed, the general relations of the ones associated with it were not sufficiently clear for an attempt to be made to identify them. A comparison of the section at Mr. Stephens' (see plate VII) with sections at other places, containing some equivalent beds (see plates VI and VII), will make the reason of this apparent.

*Which were made with an uncorrected aneroid barometer, and, in consequence, are not entirely free from possible error.

†It must be understood, however, that any revisions that may become necessary will relate more particularly to the vertical distances between some of the beds than to the identification of them. It is also to be borne in mind, that the total number of beds of coal will not be affected thereby.

Plates II to VII, inclusive, present the local sections upon which the general section was founded, and of which descriptions will be found in the special account of localities.

The following is a table of analyses, made by the chemists of the Survey, of the samples collected from several of the coal beds of the county:

	1	2	3	4	5	6	7	8	9	10
Moisture	5.54	3.94	4.80	4.80	3.50	3.34	3.50	3.30	4.80	5.10
Vol. combustible matters	35.66	37.86	33.70	35.60	36.30	35.84	35.00	36.76	35.80	30.70
Fixed carbon	48.88	50.48	68.76	49.66	50.92	54.36	52.50	52.60	45.20	54.24
Ash	9.92	7.72	9.24	9.94	9.28	6.50	9.00	7.34	14.20	9.96
Sulphur	4.199	3.128	3 364	3 180	3.524	3.826	3.390	2.604	3.015	2.164
Specific gravity	....	....	1.386	1.356	1.345	1.315	1.421	1.316	1.384	1.382

	11	12	13	14	15	16	17	18	19
Moisture	6.66	3.96	4.80	6.54	3.70	6.00	5.30	6.80	2.70
Volatile combustible matters	33.64	40.50	41.00	37.92	36.64	34.30	45.70	32.40	39.30
Fixed carbon	51.56	52.38	49.14	51.54	55.30	50.36	45.00	52.50	45.90
Ash	8.14	3.16	5.06	4.00	4.36	9.34	4.00	8.30	12.10
Sulphur	2.768	3.128	2.356	1.917	1.241	4.307	2.150	2.109	7.959
Specific gravity	1.357	1.282	1.295	1.305	1.321	1.387	1.273	1.340	1.413

Analysis No. 1 is of samples taken from Doering's mine, near Centretown; 2, from Morton's mine, in the same locality; 3, from L. M. Patterson's mine, at Mt. Pleasant; 4 (Coal D), from Brown's bank, in the Ben's Lick Hills, near Hartford; 5 (Coal D), from Williams' bank, near Hartford; 6, the Taylor mine; 7, the Rockport mine; 8, Stephens' mine, near Beaver Dam; 9 (Coal E), from the bank of Rough creek, at the mouth of Brush creek; 10, from M. Sandifur's bank; 11, from Wm. Warden's, half a mile northwest from Centretown; 12, Henry Thomson's bank (the Elm Lick coal); 13, Wm. Hines' bank, sample taken from below the parting in the coal (the Elm Lick coal); 14, same locality, from above the parting; 15, Martin's bank, from the lower member (the Elm Lick coal); 16, Berry and Walker's land, in ravine draining into the North Fork of Muddy creek, near the Hines bank; 17, "old opening" on Berry and Walker's place, near the Hines bank; 18, from L. D. Taylor's bank; 19, from A. Woodward's coal.

IV.

LOCAL OBSERVATIONS.

In order to avoid repetition in the "County Report," which is to follow hereafter, it is deemed inexpedient to give, at present, more than an outline of the local examinations made in the county.

As stated on a preceding page, the beds are so disposed, by disturbances in the county, that there is a descent in the order of the series, from Beaver Dam towards Cromwell on the south, and towards Hartford on the north.

In the region about Hartford the beds have been moved by local disturbances (as mentioned on page —); but, as compared with the series in the more southerly part of the county, they have, nevertheless, a northwardly rise.

This arrangement of the beds naturally tends to throw the higher coals along the central part of the district, as is shown to be the case in the "Coal Ridge" and the hills in its vicinity. The higher coals are not, however, confined to such a position, but, where the topographical conditions are favorable, they are found (frequently as isolated masses) both to the north and to the south.

At the old Taylor mine, on the Green river, about one mile below Cromwell, and at Cromwell and in its vicinity, there are, collectively, six coals, the uppermost coal that is distinctly exposed being Coal D, which is the bed formerly worked at the old Taylor mine.* On the hill above the drift, at the Taylor mine, fragments of the limestone which occurs between Coals A and B are found, but no traces of the coal beds have yet been discovered.

The following is the general section of the beds at the mines, and at Cromwell and vicinity:

*This place is mentioned on page 158, volume I, first series Kentucky Geological Reports, D. D. Owen, Director.

No.	Description of Strata.	Feet.	Inches.
1	Massive Sandstone	65	
2	*Coal D* (varies in thickness)	4	
3	Space	10	
4	Thin-bedded Sandstone	10	
5	Space	32	
6	Black Bituminous Slate	5	
7	*Coal E*	out	crop.
8	Space	25	
9	Black Slate, exposed for	2	
10	*Coal E^a*	out	crop.
11	Space	10	
12	Shale, containing iron-stone concretions	25	
13	Space, about	5	
14	*Coal F*	. . .	6
15	Space	2	
16	Mottled Limestone	1	
17	Space; notably shale, sandstone and shale	55	
18	*Coal G* . . . 1 foot to	. . .	9
19	Shale	35	
20	Black(?) Slate?	4	
21	*Coal;* below the level of the river	1	6
22	Under clay	4	
23	Shale	16	

The mottled limestone and associated beds are exposed frequently between Cromwell and Kate's Hill, on the Morgantown road, towards the railroad. They are also exposed in the region about the Bald Knob Church, on the Pinchico and Caney precinct road.

Near Bald Knob Church, in the road, by the dwelling of Mr. Robinson (on the farm of Rev. B. F. Jenkins), the following section is exposed:

No.	Description of Strata.	Feet.	Inches.
1	Covered space, red clay on the surface	5	
2	*Coal F*	. . .	9
3	Under clay	3	
4	Mottled Limestone; has a brecciated appearance on the surface	1	
5	Sandy Shale and Shaly Sandstone	28	
6	Mostly covered; notably Sandy Shale	8	
7	Soft disintegrating Sandstone	35	

By the Bald Knob Church the coal is again exposed, with an admirable fire-clay below it. The following is the analysis of the clay:

Silica	62.760
Alumina	26.420
Oxides of iron and manganese, and phosphoric acid	1.580
Lime	.325
Magnesia	trace.
Potash	.916
Soda	.268
Water expelled at red heat and loss	7.731
Total	100.000

On A. H. Davis' land, half a mile about south 70° east from the Bald Knob Church, a limestone higher than the mottled limestone occurs. It is probably a comparatively local bed. It is coarse, granulated in texture, and grey in color. A number of fossils were found in it, among which the following species were identified: *Productus muricatus*, *Athyris subtilita*, *Spirifer cameratus*, and *Crinoid* columns. A poor, argillaceous iron ore was seen resting, in places, above the limestone. It also is fossiliferous, and may accordingly be presumed to be nearly, if not quite, as extensive in area as the limestone. The ore, in fact, seems to be derived from the limestone. The mottled limestone is exposed below in the hill-side, about two hundred and fifty yards away from the upper bed. We accordingly have a very good level (in these two beds) from which to work when examining the structure of the contiguous region. The upper limestone does not, however, appear to be constant. It is, perhaps, probable that it is developed most fully in the region just now under consideration, and is not to be found, as a rule, outside of a restricted area. Of this, however, the evidence is limited.

On lands belonging to Mr. L. D. Taylor and Mr. F. M. Gillstrap, about one mile north 85° east from Bald Knob Church, a coal is found at a level below the mottled limestone; the cherty limestone containing *Prod. muricatus* is also exposed. The connection between the upper and lower part of the section is probably to be obtained more easily in this vicinity than elsewhere in the county.

The following is the section of the beds exposed here:

No.	Description of Strata.	Feet.	Inches.
1	Granular Grey Limestone, about	2	
2	Space	35	
3	Mottled Limestone	2	
4	Space 70 to	80	
5	Fossiliferous Limestone and Chert	1	
6	Argillaceous Shale	20	
7	*Coal*	2	7½

By correlating this section with the ones obtained at Kate's Hill and in the vicinity (near Beaver Dam), we obtain a very fair knowledge of the arrangement and number of the beds from the summit downwards, for about three hundred and twenty-five feet.

The coal, No. 7 of the section, seems to be the equivalent of one to be seen, when the water is low, in the bank of Rough creek, at the Hartford water-mill. Between the lower cherty limestone and the mottled limestone a massive, incoherent sandstone occurs, filling up the larger part of the space.

From the region about Bald Knob Church, towards Beaver Dam, the beds sink towards the northwest.

The mottled limestone is seen occasionally along the Hartford and Morgantown road, south of the railroad, plainly showing this feature. Beyond the railroad the beds soon begin to rise.

On Kate's Hill the mottled limestone makes its last appearance south of the railroad. The general section of the strata forming Kate's Hill, and the ridge in which the coal banks of Mr. Albert Brown, Mr. Poyner, Mr. Stephens, Mrs. Austin, and the Taylor coal mines are opened, shows the beds from Coal A downwards to the sandstone below Coal F. The connection between the beds is very plain.

On Mr. Brown's place Coal D is especially well developed, being five feet seven and three fourths inches thick. Its usual thickness is four feet eight inches. Coal E is found at forty-five feet below Coal D, and is to be traced on to Mr. Poyner's land, where a still lower coal is to be found, which has been mentioned hitherto.

Towards Elm Lick and Rosine, from Beaver Dam, the beds ascend. The Elm Lick coal is brought to view, by the upward rise, at several places a short distance southwardly from Elm Lick, and also at Mr. Martin's coal bank, about one mile, or a little more, westwardly from the station, north of the railroad.

At Mr. Henry Thomson's coal opening, two miles south from Elm Lick, the coal is more than ordinarily thick. The following is a description of the bed at this place:

a. Bluish drab argillaceous Shale			4½ feet.
b. Coal, divided thus:			
b'. Coal	17 inches.	}	6⅓ "
b''. Clay, containing stigmaria rootlets	18 "		
b'''. Coal	41 "		

The coal dips north 20° west, but at what rate could not be determined.

The bed is also exposed on land belonging to Mr. Julius Edward Otto, about one mile and a half southwest from Rosine. The upper member here measures twenty-one inches in thickness. Mr. Otto has drifted into the coal on his place, and it has been wrought in a limited way.

A short distance from Mr. Otto's drift, passing towards Rosine, but on the opposite side of the ridge, Mr. Robert E. Chiles has made entries in the coal at two places. Both entries were nearly filled with débris at the time these examinations were made. The thickness of the lower member of the coal could not be determined. The upper member measures twenty to twenty-one inches, and the clay parting seventeen and one fourth inches in thickness. Before reaching Rosine the coal seems to overshoot most, if not all, of the hill-tops. It is possible that it may be found in the knob just northeast of Rosine, the top of which is one hundred and thirty feet above the railroad at the station; but this is entirely conjectural.

Descending from Rosine towards Elm Lick, the beds dip rapidly in that direction, and the coal, which is wrought at Martin's bank, about half a mile northwardly from the Elm Lick water-tank, is brought down to a level, comparatively, forty or sixty feet above the railroad at the water tank.*

*Of course this is not the height at which the coal would lie, were it present in the hill at the tank—the element of dip being yet to consider in the calculation.

At Martin's coal bank the bed measures as follows:

a'. Coal	1 foot 6 inches.
a''. Clay parting	6 "
a'''. Coal	3 " 2 "
	5 " 2 "

The coal was measured where it had been freshly exposed, and may increase somewhat in thickness when followed under a better roof.

Journeying, in a somewhat northwestwardly direction, from Martin's bank towards Hartford, higher beds come to view. The fall of the beds is still rapidly towards the northwest. The Fusulina chert appears near the Morgantown road, about half a mile a little northeast of Dr. Berry's place, on the Morgantown road, and there it and the beds associated with it form the structure of the region on towards Hartford.

On Dr. W. J. Berry's land, about four miles from Hartford, the coal underlying the Fusulina chert crops out in a ravine draining towards the Morgantown road. The coal measures thus:

a'. Coal dirt	7 inches.	}	19 inches.
a''. Clay	6 "		
a'''. Coal dirt	6 "		

The coal is underlaid by argillaceous shale, the upper part merging into an inferior sort of fire-clay immediately beneath the coal. Scattered fragments of the Fusulina chert are found on the hill-side above the coal.

The same coal is exposed in the road by Mr. Wm. Taylor's house, about two and a half miles from Hartford. But between Taylor's and Berry's there seems to be a considerable swell in the beds underlying the coal—a massive sandstone seeming to thicken, midway between the two places, at least twenty feet. This would be best explained by a cross-section from Dr. Berry's to Mr. Taylor's. Just beyond Mr. Taylor's a higher coal crops out, near the forks of the road, which is equivalent to the one opened on Mr. L. D. Taylor's land, and also exposed on Rough creek, at the Hartford water-mill.

The following is the section from the forks of the road to Mr. Taylor's:

No.	Description of Strata.	Feet.	Inches.
1	Earthy, porous, yellowish Limestone, abounding in *Productus muricatus*	1	
2	*Coal* (No. 41 of general section)	1	
3	Space, about	8	
4	Fusulina chert, about	...	6
5	Space . . . 10 to	15	
6	*Coal*	...	18

Proceeding northeastwardly from this place towards the Hines coal bank, the beds are seen to rise in that direction, as they mount the southwardly slope caused by the Rough creek uplift.

From Taylor's to the outcrop of Fusulina chert, on land belonging to the heirs of Richard Stephens, near the Morgantown road, about three miles from Hartford, the rise amounts to fifty feet; thence to the large spring on Hon. E. D. Walker's land (known as the "Nall's tract"), about two miles and three quarters north 70° east from Hartford, where the Fusulina chert is again exposed, the rise amounts to forty feet; and thence, to Hines' coal bank, the rise is fifty feet. Proceeding northwardly from Hines' bank, the coal wrought there, which is the equivalent of the Elm Lick bed, soon overshoots the tops of the lower hills.

At the Hines bank, which is about four miles south 80° east from Hartford, the Elm Lick coal has been wrought considerably. Two other openings in coal have also been made in the vicinity, but no mining done.

The following is the section of the beds in this vicinity:

No.	Description of Strata.	Feet.	Inches.
1	Fusulina chert	out	crop.
2	Space, not fully determined on account of dip in the beds. May be from . . . 20 to	40	
3	*Coal*	...	26
4	Space, about	45	
5	*Coal*—the "working" bed—divided thus: *a.* Coal . . . 1 foot. *b.* Clay . . . 4 to 5 inches. *c.* Coal . . . 2 feet 6 "	3	11
6	Sandstone, base not seen.		

This place is about two miles and three quarters, in a northwestwardly course, from the Martin coal bank, near Elm Lick.

Towards Hartford the beds sink and the Elm Lick coal disappears beneath the surface.

Two distinct coals make their appearance at Hartford, one at the water-mill and one in the left bank of Rough creek, just below the bridge over the stream, on the Owensboro' road. Apparently the coals lie near to each other in the series, but a computation of the dip shows the contrary to be true. From the Foreman grave-yard, where the limestone which overlies the lower coal is exposed, to the coal at the bridge, the dip is rapid. The condition of the beds can be well shown only by a cross-section, which may be given hereafter.

The following section exhibits the order of the beds about Hartford:

No.	Description of Strata.	Feet.	Inches.
1	Soft disintegrating Sandstone, top not seen	5	
2	Ochreous drab Shale	15	
3	Dark blue Shale	2	
4	Black bituminous Slate, containing fish scales	1	6
5	Coal	1	2
6	Under clay merging into shale below	6	
7	Grey shaly Sandstone and Shale	21	
8	Space, about	57	
9	Limestone (seen at the water-mill and at the Foreman grave-yard)*	6	
10	Shale, &c.	10	
11	Coal	...	11
12	Under clay; very impure, base not seen	1	
13	Space†	8	
14	Fusulina chert	...	6
15	Space . . . 10 to	15	
16	Coal	1	6

* Described in a following section.

† From No. 13 to No. 16 relates to the section by the Johnston house, at the forks of the Hartford and Beaver Dam and Morgantown road.

The limestone, No. 9 of the section, is well seen at the Foreman grave-yard, but the best exposure of it is in the bank of Rough creek, by the water-mill, just above Hartford. The following are the details of the section there:

No.	Description of Strata.	Feet.	Inches.
1	Drab argillo-arenaceous Shale; underlies a disintegrating Sandstone (top not seen)	5	
2	Bluish, earthy, shelly Limestone. In places somewhat concretionary in structure. Has an irregular fracture, and may be split into thin plates. Abounds in fossils, viz: *Spirifer cameratus*, *Chonetes mesoloba*, *Productus muricatus*, *Athyris* (*subtilita?*), *Productus Prattenianus*, *Prod. Nebrascensis?* an *Aviculopecten*, etc.	6	
3	Dark calcareous Shale; becomes quite calcareous at the base, and there merges into a coarse earthy lime rock. Contains fossils . .	8	
4	Tough, coarse-grained, dark lime rock	. . .	4
5	Very dark argillo-calcareous material, closely filled with *Productus muricatus*, and containing numbers of *Chonetes*.	2	
6	Black carbonaceous Shale, with "streaks" of coal traversing it . .	. . .	1½
7	Coal	. . .	11

At the Foreman grave-yard the limestone, No. 2 of the foregoing section, is seen, exhibiting its usual appearance in this district when removed from such constant action of moisture as that operating on it at the water-mill. It seems to be somewhat pyritiferous, and, in some places, is dark blue and hard, frequently with a soft crust. Usually, however, there seem to be two beds—the upper one being a bluish, earthy, shaly limestone, with occasional hard and more compact parts; the lower bed being a pyritiferous blue limestone in the interior, but with a very thick, soft, greenish and yellowish crust —the crust being filled with fossils. The two beds seem to merge into each other. The principal fossils of the shelly bed are, *Spirifer cameratus* (which are usually large) and *Productus Prattenianus*. The lower bed is filled with *Productus muricatus*. On the slope above the limestone ochreous concretions, containing unusually large specimens of *Productus muricatus*, were found.

The following is the section here:

No.	Description of Strata.	Feet.	Inches.
1	Covered space from hill-top	28	
2	Sandstone	3	
3	Covered space	7	
4	Sandstone	2	
5	Covered space	30	
6	Coarse bluish Limestone, breaking with a hackly fracture	1	
7	Covered space	1	
8	Coarse, earthy, greenish Limestone, containing many fragments of fossils, many of which seem to be remains of Crinoids; many fragments of *Spirifer cameratus* were also seen	1	6
9	Shelly blue Limestone, containing *Spirifer cameratus* and *Producti* .	8	

The coal at the Hartford bridge has, by others, been referred to Coal D (No. 9 according to Dr. Owen's nomenclature); the sections that have been given are sufficient to show the error of this without going further into detail. It may be remarked, however, that Coal D is found in the Ben's Lick Hills, about two and a half miles below Hartford, and is shown by its topographical relations alone to be much higher than the Hartford coal; besides this, the Hartford coal sinks at a considerable rate in that direction.

It is possible, however, indeed it is probable, that one or more of the beds which are known to occur below Coal D, in the more southwardly part of the county, are absent in the region nearer Hartford, and towards the northwest. But it is also possible, that at least one bed which occurs in this region is not to be found far towards the south.

In the "Sugar Loaf" Hill, near Barrett's Ford across Muddy creek, about one mile southwardly from Hartford, two coals are exposed, the upper one being Coal E. A coal has also been opened in the bed of the creek at the ford. It is reported to be nearly three feet thick; but I was unable to verify this by personal observation.

The following is the section at the Sugar Loaf Hill:

No.	Description of Strata.	Feet.	Inches.
1	Slope	38	
2	Drab argillaceous Shale	5	
3	Black Slate	2	
4	Bluish-drab Clay	...	1
5	Coal E	1	5
6	Fire-clay (mostly)	5	
7	Greenish-drab argillaceous Shale	10	
8	Covered space	10	
9	Coal smut	...	10
10	Fire?-clay	...	6
11	Covered	45	
12	Sandy and argillaceous Shale	10	
13	Coal, reported. Is said to be covered with black slate. Thickness stated at	2	8

Westwardly from the conical hill Coal D is worked, at several places, in the Ben's Lick Hills. Coals E and E^a are also found there, the beds showing a sinking towards the northwest.

The following is the section at Brown's coal bank, where Coal D is worked:

No.	Description of Strata.	Feet.	Inches.
1	Slope from hill-top	10	
2	Sandstone	10	
3	Coal dirt.		
4	Limestone	3	
5	Covered space	51	
6	Argillaceous Shale	5	
7	Bituminous Slate	1	3
8	Coal D	4	
9	Covered space	89	
10	Coal covered by bituminous Slate. Coal measures	1	3
11	Covered space to Rough creek	4	

Down the creek, near the mouth of Brush creek, Coal E is exposed, nearly level with the bed of the creek, and higher up Coal D crops out, with the limestone (No. 4 of the foregoing section) exposed high up in the hill. The following is the section obtained in the locality:

No.	Description of Strata.	Feet.	Inches.
1	Covered slope from hill-top	40	
2	Limestone outcrop	1	
3	Covered space	49	
4	Sandy Shale in thick laminæ	2	
5	Blue argillaceous Shale	5	
6	Black Slate	1	
7	Coal D, partially concealed, probably	4	
8	Under clay, with limestone masses, sometimes as a bed, through it. About	5	
9	Thin-bedded shaly Sandstone, or Sandstone in thin laminæ	10	
10	Thinly-bedded sandy Shale	38	
11	Black, slabby, bituminous Slate	7	6
12	Bluish Clay Shale, with one half an inch of coal just above the bottom	...	7½
13	Coal, divided thus: *a.* Coal 7 inches; *b.* Clay 1 "; *c.* Coal 1¼ "	...	9¼
14	Fire-clay, containing stigmaria rootlets	1	
15	Slope to Rough creek	4	

It must be said of this section, that it was measured, except where a foot rule could be applied, entirely with an aneroid barometer; accordingly, some of the distances between beds may not be given with absolute accuracy.

Coal D is also worked at Mr. Elijah Miller's coal bank, and is known to occur at other places in the locality.

On the northwardly side of Rough creek, at Mr. J. B. Bennett's place, on the Hartford and Livermore road, about three miles from Hartford, the coal bed, which underlies the Hartford limestone (seen at the water-mill there), crops out. The coal is thin; it is said to measure, when under a good roof, eighteen inches in thickness. A limestone, under which a coal dirt occurs, is found above the Hartford limestone at this place. It seems probable that it is local in its development. The following is the section here:

No.	Description of Strata.	Feet.	Inches.
1	Dark bluish-grey to dove-colored, rather compact Limestone; contains *Spirifer cameratus*, *Chonetes*, and small fragments of Crinoid columns . . . . 1 foot to	1	3
2	Space . . . . 0 to	. . .	6
3	Coal dirt . . . . 2 to	. . .	6
4	Chiefly argillaceous and sandy Shale	12	
5	Sandstone	5	
6	Space	3	
7	Blue shelly Limestone—the Hartford Limestone.	6	
8	Space	15	
9	Coal, reported to measure	. . .	15

Proceeding in a northeastwardly direction from Mr. Bennett's, the Hartford limestone is found at several localities towards Mr. Charles D. Stephens', on Rough creek, above Hartford. Several coals are found in the bluff facing the creek, at Mr. Stephens', and from their arrangement there seems to be here a distinct change in the character of the section from its appearance farther towards the south.

The following section exhibits the order of the beds here:

No.	Description of Strata.	Feet.	Inches.
1	Sandstone—massive	25	
2	Coal.	1	10
3	Massive Sandstone	40	
4	Space	5	
5	Coal.	2	2
6	Chiefly shaly Sandstone.	35	
7	Limestone; is probably not precisely in place, partially concealed.	2	
8	Coal, reported to be	2	
9	Space	5	
10	Chiefly Shale.	42	
11	Sandstone outcrop	3	
12	Covered space to the creek.	45	

Unusually thick coal is found in the region about Centertown and at Point Pleasant. So far, however, the identity of the bed has not been determined with certainty. It is believed best, therefore, to leave that question open for future solution.

At L. C. Morton's coal bank, about seven miles nearly due west from Hartford, the coal is reported to vary from eight to nine feet in thickness. It is divided by a clay seam varying

from one half inch to one inch in thickness. The lower member varies in thickness from four feet four inches to four feet seven inches. The coal is of very good quality, as shown by the analysis given on a preceding page.

The same bed has been opened on land adjoining the Morton tract to the west, at Dooring's mine. Here the coal is more than eight feet thick, as shown by the following measurements made inside the bank:

a. Coal.		3 feet 9	inches.	8 feet 4½ inches.
b. Clay.	½ inch to	2	"	
c. Coal.		4 " 5½	"	

Samples were also collected from this bank. At the time when these places were examined, the conditions were very unfavorable for obtaining accurate data upon which to base conclusions, and on this account it is deemed best to await further developments before endeavoring to identify the coal here with other known beds.

Below the coal there is a bed of iron ore of variable richness. It seems to underlie the coal on the Dooring tract and on the Morton tract, but its character is indefinite. At the Dooring mine eight feet of the ore was exposed, from which chippings for analysis were taken. According to Mr. W. C. Morton, the base of the bed was four feet lower than the bottom of the exposed portion. The analysis of the ore is given beyond.

What *seems* to be the westward extension of the Morton coal is wrought at Point Pleasant. The bed could not be well examined at the time the region was visited, as the bank was not in operation. But, from examinations made at the mouth of Mr. Patterson's drift, the bed seems to be eight and a half feet thick in places, taking into account two feet of poor coal towards the middle. The following section exhibits the arrangement of the beds at Point Pleasant:

No.	Description of Strata.	Feet.	Inches.
1	Sandstone	15	
2	Clay . . . . 2 to	. . .	4
3	Coal divided thus: *a.* 4 feet good Coal *b.* 2 " poor " *c.* 2½ " good "	8	6
4	Covered space, chiefly Clay?	6	
5	Limestone; mottled drab and ash, and drab and ferruginous-red. In some parts contains *Martinia plano convexus*. . . 18 inches to	2	
6	Clay Shale	5	
7	Massive Sandstone extending to the Green river	50	

The coal at Point Pleasant rises apparently between 5° and 10° north 40° east. The samples collected here for analysis were taken from the bed twenty yards in from the mouth of the entry, at Patterson's drift.

A number of coal openings, which were visited in the county, have not been described, as a discussion of them belongs properly in a detailed "County Report," which it is the intention to prepare hereafter.

Following are analyses of the most promising ores of iron found in the district covered by this report:

SAMPLES FROM DOORING'S ORE BANK.

	No. 1.	No. 2.
Iron peroxide	44.594	44.916
Alumina	20.419	13.204
Lime carbonate	trace.	trace.
Magnesia	.248	.176
Phosphoric acid	.287	.280
Silicious residue	26.550	32.504
Water	8.860	8.920
Total	100.958	100.000
Metallic iron	31.216	31.241
Silica	23.420	24.46
Phosphorus	.125	.177

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ASHBY'S ORE.

Iron peroxide	61.179	Metallic iron	42.825
Alumina	15.503		
Lime carbonate	trace.		
Magnesia	.176		
Phosphoric acid	.648	Phosphorus	.283
Silicious residue	13.830	Silica	9.96
Water	9.273		
Total	100.609		

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GEOLOGICAL SURVEY OF KENTUCKY.

N. S. SHALER, Director.

REPORT ON

THE TIMBERS

OF THE

DISTRICT WEST OF THE TENNESSEE RIVER,

COMMONLY KNOWN AS THE PURCHASE DISTRICT.

BY L. H. DeFRIESE.

Part VI. Vol. V. Second Series.

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INTRODUCTORY LETTER.

N. S. SHALER, *Director Kentucky Geological Survey:*

DEAR SIR: In the following report on the timbers of that part of Kentucky lying west of Tennessee river, some distinctive features of that district will be noticed. First, that the timber changes are due not, as in the parts of Kentucky previously studied by me, to geological changes, but mostly to topographical changes. Second, that the whole of the Purchase is comparatively level. Third, that a very small change of level usually produces a marked effect upon the timbers, and thus prevents the monotony which might be expected. Fourth, that no other part of Kentucky offers such facilities for studying the ultimate effects upon the timbers of the fires by which the woods were regularly burned for a great number of years. I have endeavored to make the most of my limited opportunity for observation in all these directions.

I wish to tender my thanks to the people of the Purchase for kindness shown me while I was among them.

Very respectfully,

LAFAYETTE H. DEFRIESE.

NEW YORK, November, 1877.

REPORT ON THE TIMBERS OF THE DISTRICT WEST OF THE TENNESSEE RIVER.

GENERAL REMARKS—GEOLOGY AND TOPOGRAPHY.

There is probably no part of Kentucky where topography has more, and geology less, to do with the distribution and general character of the timbers than in what is known as the Purchase—that is, that part of the State lying west of the Cumberland river. From this it may be inferred, at once, that the species of timbers met with are pretty much the same throughout the entire seven counties which go to make up the region under discussion. There are upland timbers and lowland timbers, but there are few of those marked changes in forest growth which one meets with where timbers are more influenced by geological structure than by topography. Of geological change, if we except one or two spots where the limestone extends across the Cumberland river, there is none sufficient to affect timber growth. The whole of this Purchase region, with the exception mentioned, is apparently of tertiary age, and consists of more or less rounded whitish or reddish pebbles. In what may be called the bed-rock of the region, these pebbles are cemented together with clay, containing a good deal of iron, into an extremely hard and tough reddish conglomerate, called by the people *iron cement*. Overlying this cemented rock there is a bed of loose pebbles and sand varying from a few inches to fifty feet thick. Where the pebbles themselves form the surface of the soil, it is needless to say that the timbers consist of black jack and scrub oak. There are no mountain axes in this part of Kentucky to diversify the topography, but, owing to the peculiarity of the formation, a difference of level of only a few feet will, in most localities, completely change the character of the timber. From this it follows that the number, size, and distribution of streams are of the greatest importance in considering the present and future value of these Purchase timbers. The streams are important in considering the *future* value of the timbers, because, as I have previously shown,* wherever the white oak is the principal forest tree, other timbers are succeeding it as fast as it is cut away. This succession takes place much slower on bottom lands than elsewhere, for there are few swamp timbers to supplant white oak, and there is no danger of upland timbers doing so along streams. The water timbers are strongly marked, and it seems impossible that they could ever be supplanted by upland timbers. So there is far less tendency in swamp white oak to disappear along the streams, than there is in the upland white oak to disappear from the body of the Kentucky forests. The same may be said of other swamp timbers, so that the number and character of the streams are very important.

A glance at the map of this part of Kentucky will show that, in these seven counties, there are no less than five streams of importance, along all of which the timbers are very fine indeed, and are likely to remain substantially the same in kind. Besides these large streams, smaller creeks and branches form a perfect net-work over the greater part of the region. Leaving out of consideration the timbers along these streams, the forest growth varies considerably in these counties. Speaking generally, the timbers through the eastern parts of Marshall and Calloway counties are good, as are also those through the western parts of Hickman and Ballard.

A belt extending directly through the Purchase country, embracing less than one third of it, with its centre line passing through Mayfield, will contain about all of the poor timber to be found in this entire corner of Kentucky. And, inasmuch as Mayfield creek passes through almost the entire length of this central belt, and its tributaries and those of Little Obion river ramify through it in every direction, along all of which streams the timbers are very fine, it will be seen that this

*See Report on Tradewater Timbers, vol. V, this series.

comparatively poor strip of forest country is not devoid of valuable timber growth. There is an area of more or less flat table land lying south of Wadesboro, between East Fork of Clark river and the head waters of Mayfield creek, in which, if we except a few small streams, no water is to be found. I call especial attention to the position of this strip of table land here, for it becomes of importance further on in the Report, in the discussion of the succession of timbers.

DRAINS UPON THE TIMBER AND THE TIMBER RESOURCES OF THIS DISTRICT.

At Paducah there are several extensive timber establishments, the principal of which are those of Langstaff, Orm & Co., and McKnight & Co. The former firm claims to have the fastest saw in the world, with which they cut 8,204 feet of lumber per hour. They average 80,000 feet of lumber per week the year round, and keep their yard stocked with 2,000,000 feet of ready-sawed and dried lumber. The principal timbers cut are, of course, white oak and liriodendron (yellow poplar); but, in addition to these, are also elm, ash, hickory, sweet gum, cotton tree, yellow pine, cypress, walnut, cherry, etc. The white oak, gum, and cypress are obtained, to a considerable extent, from the State of Kentucky, from which they get about one third of their timbers. The value per thousand feet of these timbers, in the log, at Paducah, is as follows: Oak, $6 to $10; poplar, $5 to $8; walnut, $10 to $15; white hickory (second growth), $10; sweet gum, $3 to $5; cotton-wood, $3 to $5; pine, $8; cherry, $10 to $15, and so on. McKnight & Co. saw 2,000,000 feet of lumber annually, about 50,000 feet of which is walnut. More than two thirds of all the timber sawed in Paducah is brought down the Tennessee river, which forms a convenient and cheap means of transportation for the vast forests that crowd its banks from its mouth to its head. However, the Paducah lumber establishments have largely drained the lower Tennessee district, and the timbers are now floated down from far above. The time will come, though I think not soon, when the Purchase region and the Tradewater country will be called upon to furnish the timbers which are now furnished by the upper Tennessee. The only practical difficulty in the way is, that Clark river, the only stream penetrating the Purchase which is available for floating timber to Paducah, is so flat and sluggish, and has so little fall, that the floating of any considerable raft of timber upon it will be a matter of some difficulty. The admirable timbers that grow all along the smaller streams of the Purchase country can be reached only by local saw-mills or by railroad. Lumber establishments at Hickman can float timbers down Mayfield creek and Obion river.

At present, so far as I am aware, the drain upon the timbers of the Purchase region comes from the establishments at Paducah and from local mills. The two Paducah firms mentioned above saw an average of 6,160,000 feet of lumber annually. Not more than one third of this amount is obtained from Kentucky, and, at most, not more than 2,000,000 feet of it can come from the Purchase. If we count an average of ten good lumber trees to an acre, which would be a low average along the streams in this part of Kentucky, and allow 500 feet of sawed lumber for each tree, which would also be a low average, we shall have 5,000 feet of good lumber in each acre of ground. At that rate, these two firms, to obtain their 2,000,000 feet of lumber, annually strip 400 acres of ground of its valuable timbers. That is very little, compared with the hundreds of thousands of acres of fine timbers lying along all the streams in this part of Kentucky. It is impossible even to estimate the amount of timber used by the local saw-mills, which are scattered along all the streams wherever a good body of timber is to be found, and which change their location as the timber is exhausted. I think it safe to say, though, that they saw from 3,000,000 to 5,000,000 feet of lumber annually. If this be true, at the estimates given above, they now clear-up from 500 to 800 acres of timber land yearly, and something like an annual timber drain of 1,200 acres is made upon the Purchase country. This timber, in the unsawed log, is worth about $50,000. There are not less than 500,000 acres of land in the Purchase which will come within the above estimate of timber production; so, at this estimate, only about one four hundredth of the valuable timbers is now cleared-up annually. At this rate, the timbers can easily reproduce themselves, and the drain is not at all an alarming one. At the same rate, considering one third of the land to be under cultivation, the present forest of the Purchase alone would be worth $10,000,000 or $15,000,000. Even if the present drain upon the Tennessee river country were all turned to the Purchase, less than 2,500 acres of timber annually would be destroyed, or only about one two hundred and fiftieth of the whole. The forests could easily reproduce themselves at that rate, except in the upper woodlands, where, as I have elsewhere shown,* other timbers take the place of the white oak as that is cut away. Of course, all this timber wealth is not immediately available, and it is well that it is not so. Upon the whole, there is not much to be feared in regard to the present or future timber supply of the Purchase region. It is scarcely possible that a greater demand than the last estimate will be made upon it at any time in the near future. When such demand is made, however, it will probably be concentrated along the Clark river, where the facilities for cheap transportation are best, and, in that case, a few years would suffice to strip this stream of its most valuable forests. But the reserve supply of timbers, as I have shown above, is so great that no prospective demand can cause a dearth of them.

There is one great difficulty, as I have previously hinted, in getting at the splendid forests of the Clark river region, and that is, that the stream is comparatively shallow, its bottom very flat, and the water sluggish. The difficulties of rafting on such a stream are greater than they would at first seem. For instance, the lumber establishments at Paducah desire their logs brought to them in their entire length, varying from thirty to seventy feet, so that they can cut from them plank of

*Report on Tradewater Timbers, vol. V, this series.

any length demanded by their customers. The finest timbers on Clark river are hickory and white oak; but a green hickory or white oak log, forty to sixty feet in length, will not float and it takes great buoying power to keep it up. Not only is Clark river too shallow for such logs, but it is not wide and open enough to allow the passage of rafts large enough to support them. On the Tennessee river, a wide raft of tens of thousands of feet is formed, in which such logs as these alternate with seasoned poplar, which is sufficiently buoyant to support the whole. The stream is broad and deep enough, and has sufficient fall to allow of the easy transportation of these enormous rafts. Of course the only way out of the difficulty is to form small rafts, of only a few logs; but as it is comparatively a good deal more expensive to float a small raft than a large one, we need not expect to see much demand for the Clark river timbers, until those along the Cumberland and Tennessee rivers have become sufficiently scarce and inconvenient of access to render the cost of procuring them as great as that of floating the Clark river timbers.

TIMBER VARIATIONS.

The timbers in this part of Kentucky differ very little, in kind, from the timbers on the older formations of the State. The only new timber met with is the cypress (bald cypress), which is now found immediately on the banks of all the larger streams, on all marsh lands and swampy grounds. Its presence is not due to the formation, for it appears elsewhere from New Jersey southward, on various formations. Why it does not appear in other parts of Kentucky, I do not know, unless it be that a low, level, moist country is required for its growth. But changes of timbers are often, so far as can be discovered, capricious. Magnolias are found in great abundance on the upper Cumberland; down towards the Ohio I have not met with a single one. So it may be, so far as regards geological formations, with the cypress. The timber is light, fine-grained and durable, and

the trees along the large streams, in this part of Kentucky, grow to a height of eighty to one hundred feet, with trunks from three to seven feet in diameter.

There is a marked peculiarity in regard to the growth of the beeches in the Purchase. They are not found in great numbers along the large streams, as they are in the Rough creek region, along the North Cumberland, and in nearly every other part of Kentucky. Along the principal streams, here, very few beeches are met with, and they can hardly be said to form a part of the timbers along Clark river, Little Obion river, and Mayfield creek. They are scattered through the bottoms of small streams, but are not conspicuous even there. A Kentucky swamp without beeches strikes one peculiarly. I could not see any reason for their general absence from the bottom lands of this part of Kentucky.

The abundance of Spanish oak in the Purchase country is worthy of note. Nowhere else, here, have I seen that timber form so conspicuous an element of the forest growth.

Hickory does not form a large percentage of the upland forest timbers, and one will often travel for a mile or two without seeing a single hickory tree. Along the streams and on low grounds, however, the hickory is very fine and valuable. I know of no finer bodies of hickory timber in this country, than are to be found along Clark river and Mayfield creek. The shagbark, pignut, and white hickories are the finest varieties, and of these I have often counted, within sight of where I stood, a dozen which would average ninety feet in height, with diameters of from two to four feet.

Chestnut, whose unaccountable presence on one side of Green river, and absence on the other side, I noticed in a former report (Tradewater Timbers, vol. V, this series), seems to be as arbitrarily distributed in the Purchase as anywhere. About five miles from Benton there is a little creek running into East Fork of Clark river, called Chestnut creek. It heads up between two high hills, whose faces form a topographical synclinal. On these two hill slopes, facing each other, a few chestnut bushes are found; but they stop absolutely and abruptly at the tops of these two slopes, and on the other sides of the same hills not a chestnut bush is to be found. Nor is there any chestnut in any other part of this section of the country. I was told that there were a few bushes five or six miles off on Middle Fork, but I did not see any. How these chestnut bushes came to grow upon the faces of these two hills I cannot imagine; for they could not have come from seeds floated down the stream, inasmuch as the mountain above the head of the stream has no chestnut on it, and never has had any so far as I could find out. The people have recognized the peculiarity of the growth, as is indicated by the name of the stream. A few chestnut bushes were found in one or two other spots in the Purchase, whose presence and limited distribution are as hard to account for as those of the Chestnut creek timbers.

There is a considerable amount of black walnut scattered through the Purchase country, most of which is found high up on the heads of streams. There is more or less of it found on the head waters of all the streams, but an especially large quantity is met with on Brush creek and on the streams that form the North Fork of Obion river. There is no market for walnut timber in this part of Kentucky and no value is attached to it. It is ruthlessly cut and sawed by the little saw-mills that spring up wherever there is a local demand for lumber. It sells for about three dollars a tree, and a piece of walnut timber that would bring $150 in New York is considered dear at $4 or $5. There is an amount of improvidence shown by Kentucky people in dealing with their forests which would astonish any other civilized people. It is not shown in regard to the walnut alone. In the wide flat woods south of Paducah there is considerable valuable white oak, which is all the more valuable because it is within a few miles of its best market; but I constantly noticed the people cutting this white oak for fuel, notwithstanding the woods are full of Spanish oak and black oak, which make fully as good fire-wood, and are valuable for nothing else. As a rule, the tree nearest to the house

of the owner is the first one sacrificed, regardless of its value. Within a few years, by the time the timber establishments of Paducah turn to the Purchase for their supplies, this flat woods will be almost stripped of its white oak timber, and only the Spanish oak and black oak, which are everywhere succeeding the white oak, though comparatively valueless, will be left as "brands snatched from the burning."

The distribution of the liriodendron (poplar) timber in the Purchase is about the same as that of the white oak. It is found in great abundance on nearly all the streams, large and small, and the principal demand for it is that made by local mills, which, of course, waste large quantities of it. But the reserve supply for future use is so great that no present apprehension need be felt. The finest body of upland white oak and liriodendron in this part of Kentucky is probably between Dublin and Clinton, near the line of the two western railroads across the Purchase. To this statement a rather curious exception must be made. About six miles from Clinton the white oak suddenly disappears, even from low grounds, and on a belt about one mile wide it is almost wholly absent. Here, black and Spanish oak are very fine and heavy, and with them are liriodendron, white elm, etc. About seven miles from Clinton the white oak abruptly begins again, and forms, as it did before, about forty per cent. of the forest growth. I cannot account for this gap in the white oak, unless it be that long ago a hurricane passed through the region and destroyed all the timber in its track, in which case, as I have elsewhere shown, Spanish and black oak would succeed the white oak in the new forests.

In the flat woods south of Paducah, referred to above, the timbers often alternate most curiously. Here white oak is the principal, almost the only, timber; two hundred yards distant, Spanish oak and black oak have succeeded the white oak; at the same distance further on, these timbers have disappeared, and only post oak or hickory is to be seen, and all this without the slightest change of level, or the least apparent reason therefor. In places, all these timbers grow together; again, they grow only in streaks. After passing this flat woods, there are two principal causes of change in the timbers: one is change of height above drainage, which always produces corresponding changes in the species of timbers; the other is change in the position of the gravel beds relative to the surface of the ground. Underlying the whole of the Purchase country is a bed of pebbles, whose thickness I could not accurately ascertain. This pebble bed is, in some parts of the country, as much as fifty feet below the surface of the ground; in others, for miles, it is on a level with the surface, whose whole formation consists of these pebbles. I did not have the time or the means to investigate the course of these pebble beds, but wherever they lie near to, or form the surface soil, the timbers are very poor, and consist mostly of black-jack and scrub oak. The fine timbers are always found where these beds are at a considerable depth below the surface soil.

I might call attention here, in passing, to two irregular marsh-ponds of the Purchase, one a few miles south of Paducah, the other a few miles north of Mayfield. They are low, undrained marsh lands, the former irregularly round, the latter oblong, and both heavily timbered with swamp timbers. Buzzard pond, as the one near Paducah is called, contains a great deal of bartram oak, over-cup, the people call it. Cypress pond, near Mayfield, takes its name from its principal timber. It is one of the cypress swamps often found in the Southern States.

SUCCESSION OF TIMBERS.

Between Murray and Mayfield there is a considerable area of more or less flat table land, through which no water passes, except the extreme head waters of West Fork of Clark river, and a few other little branches, most of which are dry nearly all the year. I was surprised, after leaving Benton and passing into this table land, to find that the woods consisted only of saplings or tall, slim, young trees, from forty to seventy feet in height, but not more than twelve to twenty inches in

diameter. At a distance, this forest appears very heavy on account of the height and extreme density of these young timbers; but on nearer approach, not an old tree can be found. This peculiar growth extends beyond Murray, and, as I afterwards found, occupies the entire table land, to which I have previously called attention. I examined closely this young forest, and found that its principal timbers are black oak and red oak, and that scarcely a single white oak is to be found. My study of the Tradewater timbers had convinced me, that wherever the present forests of Kentucky are, by any means, destroyed, white oak does not form an element of the new forest growth, but that it is wholly supplanted by black oak and red oak. (See Report on Tradewater Timbers, vol. V, this series.) I at once concluded that the whole forests of this table land had been destroyed thirty or forty years ago, and that the new forest had succeeded that universal destruction of timbers in which the white oak had perished forever. I then passed off into the head waters of West Fork of Clark river and those of Mayfield creek, and noticed that as soon as these streams became large enough to have considerable bottoms, and to have water in their beds the year round, that in these bottoms the old forest timbers, consisting of white oak, poplar, and other timbers commonly met with, still exist. But these timbers are limited strictly to the swamp, at whose margin they give way abruptly to the young forest. Of course, the mystery was at once solved. Fire is the only agency that could destroy the forests over such a wide area, and leave none but the timbers in damp places standing intact. I had before studied the effects of burning off the woods upon the forest timbers, and had pointed out the fact that the people living along the foot of the Black Mountains of Kentucky are rapidly destroying some of the finest timbers in the United States, by pursuing this practice year after year. (See Report on North Cumberland Timbers, vol. IV, this series.) It immediately suggested itself to me that the cause I had seen in operation in the Black Mountains had completed its work in this part of the Purchase.

I called on Mr. Waterfield, one of the oldest residents of this part of Kentucky, who lives about six miles from Murray, for information. He told me that thirty years ago this whole region of country was a perfect prairie, in which not a single bush was to be found, except along the streams, and that this result was due, as I had suspected, to the practice of burning off the woods yearly, in the late fall or early spring, for the sake of the "range." This practice, when continued year after year, produces two results, both of which I pointed out in speaking of the Black Mountain timbers: it kills off the old forest growth more rapidly than it would be removed by the ordinary agents, by burning and crisping the outer bark every year, and exposing the body of the tree to dampness and decay and the ravages of worms, and it destroys, every fall or spring, the bushes which have grown up since the preceding spring, and which have not yet attained sufficient size to withstand the heat. Evidently, if this process is kept up long enough, the old forest will have passed away, and no new one will have come on to take its place. Suppose this stage to have been reached over an extensive area of almost unwatered country: of course, during the next summer, after the last old tree had passed away and the young bushes had been burned down in the fall or spring, leaving the country absolutely bare, many other young bushes would spring up from seeds and roots still buried in the ground, and, if let alone, would form such a forest as we now see in this part of the Purchase. But if we suppose the process of burning to be continued year after year, it is evident that, before a great many years had passed, the last of the buried seeds would have sprouted, and the last root have exhausted itself and died. We should then have a vast expanse of country, not only without a tree or bush, but without a single seed or root from which one could come. Such are now the great prairie lands of the Western States, and such has been the cause which, in my opinion, led to their barren-

ness of forests. These prairie lands were deprived of their primeval forests by a long continuance of the practice which the Indians pursued of burning off the woods yearly for the purpose of gathering nuts and hunting game. The calamity is irreparable, and Illinois, instead of boasting of the $300,-000,000 worth of timbers such as now form the glory of Kentucky, must go through the slow and expensive process of planting and culture to replace the forests which she has so lamentably lost. I am inclined to think that the burning of the woods in the strip of country under discussion did not go so far as to exhaust the buried seeds and roots of the timbers; for, although the strip burnt over is comparatively so small, and so surrounded by heavy forests, that, had such been the case, seeds from these forests would quickly have spread over the burnt area, nevertheless it seems that, in that case, the young trees nearer the margin of the surrounding woodlands would be larger and older than those in the centre of the burnt district. To a certain extent, this is actually the case; but, from a close examination, I came to the conclusion that this appearance was due, not to the fact that the buried seeds and roots over the whole area had been killed and new supplies been furnished from the surrounding forests, but to the fact that, as settlements pushed into these burnt areas, the limits burned over became more and more restricted every year until the burning ceased entirely. This process would give to the present young forest the appearance of being regular and heavy, and yet of gradating into somewhat older growth as one approaches the limits of the burnt district. Besides, inasmuch as the country here slopes toward the north and all the streams flow in that direction, if the forest destruction had been complete and the seeds of the new forest had been furnished from the surrounding old forest, the trees of the new forest would have grown gradually larger as one approached the *southern* limit of the burnt area. The exact opposite is the case, and the young forest trees grow larger as we approach the old forests on the *north* of the burnt district. This shows that the present irregularity of the young trees is due to the fact that settlements pushed southward in this part of Kentucky, and that the limit of the burnt area was pushed a little further south each year for some years before the burning ceased altogether.

Luckily for the prairie lands of the United States, they are nearly all level, or the loss of their timbers would have led to so great a destruction of the lands themselves, by torrents, that no amount of human labor and ingenuity could ever have retrieved them. If the same process of forest destruction goes on in the mountainous regions of the North Cumberland, until the timbers there are entirely destroyed, nothing can avert from that country the calamity which reckless destruction of forests is now producing in the mountain regions of some parts of Europe. (See Tradewater Timbers, vol. V, this series.)

One of the most important results to be reached from a study of this once burnt district of the Purchase is, however, that my former conclusions in regard to the disappearance of the white oak are correct. Here is a strip of country, surrounded on all sides by vast forests of white oak, such as once evidently occupied this district itself, which is suddenly entirely stripped of its forest growth, except that immediately along its streams. In the new forest which succeeds this destruction scarcely a single white oak is to be found. This, taken in connection with previous observations which showed that the white oak is wanting in the young forest growth in all parts of Kentucky, whatever the character of the old growth, seems to prove conclusively that the white oak cannot hold its own in competition with black oak, red oak, and such timbers.

TIMBER IN DETAIL.

Starting out from Paducah southward along Clark river, for some miles there is found a flat table land with grayish soils, the curious alternation of whose timbers I have previously noticed. Upon this very little undergrowth is found, and what little there is consists almost wholly of black oak and Spanish oak.

In the Clark river bottom, four miles from Paducah, considerable cypress is found. The shag hickory, sweet gum, and white oak, even this near to Paducah, are very fine and heavy, and vary from twenty-four to forty inches in diameter. A good deal of liriodendron, often four feet in diameter, is also found, as well as some white ash, redbud, etc. Black locust and iron wood are also met with. Six miles from Paducah, about thirty per cent. of the timbers is white oak, and about six per cent. of them liriodendron. Black oak forms about fifteen per cent. of the old forest growth, and of the young forest growth, which is very heavy, about thirty-five per cent. Black, shag, and pignut hickories and Spanish oak are the other forest timbers. These timbers remain essentially unchanged, with the exception of local alterations, for a distance of five miles. Here the road becomes a more or less bare, white sandy ridge, with Clark river off to the right. Along the road, the timbers for some miles are not valuable, and consist nearly altogether of black oak, Spanish oak, black-jack, post oak, and black hickory. On Clark river, the bottom is wide and the timbers are very valuable. On Tennessee river, off to the left of the road as I traveled towards Benton, the valuable timbers are nearly all cut out. White oak and liriodendron, as well as white ash, are found on nearly all the small streams.

About five miles from Benton the country becomes more hilly, and the timbers more sharply divided into upland and lowland timbers. The former are Spanish oak, black oak, post oak, black-jack, and black hickory; the latter are white oak, white ash, liriodendron, white elm, shag hickory, sycamore, and red birch. Bartram oak is also found along all streams. The hilly character of the country continues for about one mile, when the East Fork of Clark river is reached. The swamp land, or bottom, here, is fully two and one half miles wide, and the timbers throughout the whole are of the very finest. The white oak is often four feet in diameter, with height in proportion, sweet gum forty inches in diameter, black and shag hickory thirty-six inches in diameter, with beautiful trunks, sixty feet in height without a limb.

Bartram oak is very heavy, and white elm is good and plenty. Liriodendron is not very large, nor are white and black ash. The best have been cut out right along the road by a small saw-mill near the crossing. But those timbers are very fine all through the Clark river bottom, and as this is usually from one to three miles wide, there lies along it a vast body of exceedingly valuable timbers.

Between Benton and Watch creek, two miles from Benton, towards Murray, the road is hilly and the timbers poor, consisting of red oak, black oak, and post oak, black-jack and black hickory. On Watch creek, the usual lowland timbers are found—white oak, liriodendron, black walnut, sycamore, birch, white elm, and red elm, with some shag hickory. After crossing Watch creek, for a distance of five miles, there is alternate hill and level. The surface soil in these levels is composed of whitish gravel, which is not cemented together. The timber is almost wholly black-jack. Even on Wade's creek there is little change in these timbers. Immediately along the banks of the creek, most of the swamp timbers are found, but they are not large nor valuable, except near the mouth of the creek, where they become similar to those of East Fork of Clark river. If we except along Rockhouse and Bee creeks, on both of which good liriodendron, white oak, black and white ash, white hickory and black walnut are found, the timbers are very poor through the high, hilly country from Wade's creek to Murray. The timbers along East Fork are very valuable even this high up; but the river bottom is growing much narrower, and the body of timber along it much smaller. The timbers remain essentially unchanged from Murray to the Tennessee line.

In turning from Murray, back toward Mayfield, one enters upon the level sandy table land before referred to, where the entire forest consists of bushes. These bushes are tall and slim, and stand so thickly on the ground that the forest could never be worth very much even if the timbers were valuable in kind; but this they are not. Of these timbers, black oak forms about forty-five per cent, red oak and scrub hickory

fifteen per cent. each, post oak thirteen per cent, Spanish oak nine per cent., and white oak two per cent. Black-jack alternates with black oak, and in some places is the only timber met with. From this composition we can form an instructive idea of what is to be the future forest of Kentucky, in case no action is taken to perpetuate the present distribution of timbers.

The monotony of this young forest growth is broken on reaching West Fork of Clark river, where timbers very similar to those of East Fork are found, except that the bottom of West Fork is narrow, and the timbers are proportionally small and unimportant. White oak, sweet gum, and liriodendron are its most valuable timbers. After crossing West Fork, the country is somewhat more broken; but the same young forest is met with until one nears Farmington. Here the timber, though still all young and of the same composition, is evidently older than that between Farmington and Murray, and clearly shows that the practice of burning off the woods ceased here before it did in the latter locality.

About five miles from Mayfield the old forest growth is reached again, with considerable white oak, laurel oak, and pig hickory in the lower grounds, and post oak, black oak, Spanish oak, and black-jack in the higher grounds. A change of level of fifteen feet is sufficient to produce this change in the timbers. About three and a half miles from Mayfield, Mayfield creek is reached, and the timbers become very valuable. They consist of white oak and liriodendron, which, together, form about forty per cent. of the swamp timbers, sweet gum, shag and white hickory, black ash and white ash, cypress, bartram oak, winged elm, and swamp laurel oak. A small saw-mill near the creek crossing does a great deal of local work. The timbers along Mayfield creek are every where very fine, and as the bottom is wide and the creek very tortuous, running through more or less of five counties of the Purchase, the body of timber that lies along it is very valuable. It will be difficult, however, to float out a large part of this timber, because, during a considerable part of its course the creek is not large enough to float out timber, and even where it is large enough, the sluggishness of its waters is a practical difficulty.

After crossing Mayfield creek, there is a stretch of country about ten miles across, between Mayfield and Clinton, which is very hilly, and whose timbers are not valuable. They consist nearly altogether of black oak, Spanish oak, black hickory, post oak, and black-jack. Very little white oak is found and less liriodendron. This lasts until the head waters of Skegg's Fork and of Bowen's creek are reached. South of this strip of comparatively valueless timbers, however, there is a section of country whose forests are very fine: I mean that belt of country comprising the numerous creeks that form the head waters of Mayfield creek and North Fork of Obion river. This section, about fifteen miles square, is a perfect net-work of creeks, no less than eighteen of which flow across it in some way or other. The timbers along these head-water creeks are very heavy and dense, and the white oak, liriodendron, hickories, etc., are of the finest. Here, too, are found the most valuable old forest walnut trees to be met with in the Purchase. Bayou de Chien creek heads in near this section also, and contains along its bottoms a valuable body of timbers, similar to those of Mayfield creek and Clark river.

Going farther north again, about ten miles from Mayfield, toward Dublin, one enters upon a tract of country where the surface gravel wholly disappears, and is found at a depth varying from twenty to forty feet. Here the general forest timbers become good again, and pignut hickory and white oak extend to the hill-tops. About two miles from Dublin the forest is splendid, and furnishes white oak, liriodendron, hickories, white elm, black locust, redbud, etc. On the high hills black oak, Spanish oak, and red oak are found. The white oak through here forms fully forty per cent. of the forest timbers. Turning northward from Clinton, the timbers remain about the same as those between Dublin and Clinton until North Fork of Obion river is reached. Here the white oak,

hickory, liriodendron, sweet gum, bartram oak, and cypress are unsurpassed. The bottom of North Fork varies from one half mile to three miles in width, and is a broad belt of the most beautiful and valuable timbers throughout the entire length of the river. A great quantity of pin oak and swamp laurel oak is also found on North Fork.

After passing North Fork the country is rather hilly again, until the region of Little Mayfield creek is reached. Through this hilly section, however, there is a great deal of white oak and liriodendron, the latter amounting to an average of probably eight per cent. of the forest timbers. There is a valuable body of timber off to the east of Blandville, on the net-work of creeks, consisting of Wilson's Fork, Mahon's creek, Sugar creek, and others which are tributary to Mayfield creek. Of course, the bottom lands on Mayfield creek grow wider as we approach its mouth, and the body of timbers along its banks grows more extensive and valuable. But north of Milburn, before reaching the net-work of creeks referred to, there is a section of country where the white oak ceases to be a forest timber. It is found only on the lowest spots of ground, and, elsewhere, is superseded entirely by black oak and Spanish oak.

About thirteen miles from Paducah, on the Blandville road, we again meet with the more or less grayish table land lying south of Paducah, throughout which white oak, black oak, Spanish oak, post oak, and black hickory are irregularly scattered, alternating one with another in a seemingly unaccountable way.

TABLES.

The following are tables of the timbers met with in various parts of the Purchase. The areas usually cover twenty-five hundred square yards of ground, more or less, are chosen at intervals of four to eight miles along the road, and are as nearly representative as such tables could be made. They are given in the order in which they were taken, which will be gathered from the previous section, "Timber in Detail."

Name.	Number.	Average diameter.	Cut.	Decayed.
White oak	16	20 inches.	3	2
Post oak	10	19 "	0	1
Black oak	3	18 "	0	0
Black hickory	3	16 "	0	0

Undergrowth of black oak and black hickory. Small growth of black gum, dogwood, black sumach, and winged elm. Small growth refers to the comparatively small and unimportant timbers, and is distinguished from undergrowth or bushes. Location, two miles from Paducah.

Name.	Number.	Average diameter.	Dead.	Decayed.
White oak	8	20-32 inches	0	2
Black oak	5	22 "	0	4
Liriodendron	2	28 "	0	0
Black hickory	5	20 "	2	0
Shag hickory	3	18 "	0	0
Pig hickory	2	16 "	0	0

Bushes consist chiefly of black oak and red oak, though about five per cent. of white oak is found among them. Small growth, as in last section. Location, a flat ridge bordering Clark river, about five and a half miles from Paducah.

Name.	Number.	Average diameter.	Dead.	Decayed.
White oak	2	22 inches.	0	0
Black oak	7	21 "	2	2
Red oak	2	19 "	0	1
White elm	1	20 "	0	0

Black hickory is in the neighborhood, but not in this section. Black oak, red oak, and white oak are about evenly divided among the bushes in this spot—the only place I have noticed where there is a greater proportion of white oak among the bushes than among the old trees. Location, level sandy ridge, about thirteen miles from Paducah.

Name.	Number.	Average diameter.	Dead.	Decayed.
White oak	16	26 inches.	1	3
Red oak	2	23 "	0	1
Black oak	1	22 "	0	0
Pin oak	1	20 "	0	0

No hickory nor liriodendron in the locality. White elm, black gum, and catalpa are found among the small growth. Location, a depression or hollow about five miles from Benton.

Name.	Number.	Average diameter.	Dead.	Decayed.
White oak	9	40 inches.	0	2
Bartram oak	3	32 "	0	1
Liriodendron	7	28 "	1	1
Sweet gum	5	35 "	0	1
Black hickory	3	30 "	0	0
Shag hickory	2	28 "	0	0
White elm	3	26 "	0	1
White ash	1	22 "	0	0
Cypress	2	35 "	0	1

The section is on the East Fork of Clark river, four miles from Benton. The swamp here is three miles wide, with timbers as fine all through. Large amount of pin oak, sycamore, red birch, and considerable black ash are also found.

Name.	Number.	Average diameter.	Dead.	Decayed.
Red oak	17	19 inches.	2	4
Black oak	13	20 "	1	2
Spanish oak	3	20 "	0	1

Post oak in this locality, but no hickory. Location, a hill-top, about one mile from Benton.

Name.	Number.	Average diameter.	Dead.	Decayed.
Post oak	8	18 inches.	0	2
Spanish oak	7	14 "	1	2
Black oak	1	16 "	0	0

Among bushes and small growth, in addition, are black hickory, persimmon, dogwood, sassafras, and black-jack. No white oak in the neighborhood at all. These timbers remain unchanged, except on streams and at the bases of hills, till the forest of young timber, previously spoken of, is reached. Location, high ridge, about five miles from Murray.

Name.	Number.	Average diameter.	Height.
Black oak	18	11 inches.	35 feet.
Red oak	5	11 "	30 "
Spanish oak	7	12 "	34 "
White oak	1	7 "	24 "
Scrub hickory	7	8 "	18 "
Post oak (scrub)	6	20 "	35 "

The young timbers are exceedingly thick, on the ground, all over the country, and the table is a good average of their character. The small amount of white oak, and the large amount of black oak, on low and high ground alike, in these woods, which have grown up within twenty-five years, is worthy of notice and earnest consideration. This is the character of the forests until Mayfield creek, three and a half miles from Mayfield, is reached. Location, six miles from Murray, a nearly level table land, very fertile.

Name.	Number.	Average diameter.	Dead.	Decayed.
White oak	9	24 inches.	0	1
Liriodendron	8	30 "	1	1
Sweet gum	6	22 "	0	0
White hickory	1	24 "	0	0
Shag hickory	2	20 "	0	1
Pin oak	2	22 "	0	0
Bartram oak	3	26 "	0	1
White ash	1	25 "	0	0

Winged elm, black gum, water birch, maple, sycamore, and cypress are also found in the locality, which is Mayfield creek bottom.

Name.	Number.	Average diameter.	Dead.	Decayed.
Black oak	10	20 inches.	1	2
Spanish oak	8	22 "	0	1
Red oak	4	21 "	0	0
Post oak	4	20 "	0	1
White oak	1	18 "	0	0
Black-jack	1	16 "	0	0
Black hickory	3	18 "	0	0

White oak and liriodendron not numerous in this locality. The oaks in the table alternate as leading timbers here. There is a good deal of white oak in the forest here, but none of note in the locality of the table. Location, more or less level, ridge country, about seven miles from Mayfield, toward Clinton.

Name.	Number.	Average diameter.	Dead.	Decayed.
White oak	13	20–44 inches.	1	3
Liriodendron	5	40 "	0	2
Sweet gum	6	28 "	0	2
Spanish oak	3	25 "	1	0
Black oak	4	35 "	0	1
Bartram oak	3	30 "	0	0
Pig hickory	2	26 "	0	0
Shag hickory	3	25 "	0	1
White ash	2	24 "	0	0
Black ash	1	22 "	0	0
Red elm	2	28 "	0	0

Cypress exists in great plenty right along the banks of the river. Location, North Fork of Obion river, between Dublin and Clinton.

Name.	Number.	Average diameter.	Dead.	Decayed.
White oak	12	26 inches.	1	2
Spanish oak	3	24 "	0	1
Post oak	2	20 "	0	0
Black oak	4	26 "	0	1
Liriodendron	2	25 "	0	0
Pig hickory	2	24 "	0	0
Black hickory	1	26 "	0	0

The white oak through here forms about forty per cent. of the forest timbers, the liriodendron about four or five per cent. Hickory is very fine. Undergrowth mostly of black and Spanish oak, with some post oak, considerable hickory, and small amount of white oak. Location, open upland forest, between Dublin and Clinton.

Name.	Number.	Average diameter.	Dead.	Decayed.
White oak	14	30 inches.	1	2
Liriodendron	7	28 "	0	0
Swamp laurel oak	6	26 "	0	0
Bartram oak	4	28 "	0	1
Red oak	3	27 "	0	1
Sweet gum	7	30 "	1	0
Cypress	2	34 "	0	1

White elm, white and shag hickory, black and white ash, pin oak, etc., are found, but not in this section. Location, Little Obion river, about seven or eight miles north of Clinton. The hickory and white oak are very fine.

Name.	Number.	Average diameter.	Dead.	Decayed.
White oak	21	25 inches.	1	3
Liriodendron	8	26 "	0	1
Black oak	1	20 "	0	0
Spanish oak	1	22 "	0	0

Pig and black hickory are in locality, but not in the section. Location, the forest along the net-work of creeks south of Lovelaceville. Dogwood, alder, persimmon, winged elm, etc., are small growths.

Name.	Number.	Average diameter.	Dead.	Decayed.
Post oak	19	21 inches.	0	3
Black oak	5	24 "	0	2
Spanish oak	1	18 "	0	0

No hickory; bushes mostly black oak. Location, an average hill-top in the forest a few miles east of Blandville.

Within twelve miles of Paducah, we pass into a flat, whitish-gray table land, whose timbers are similar to those noted on leaving Paducah and going southward on the eastern side of the Purchase.

From the foregoing tables, some interesting information can be deduced in regard to the timbers of the Purchase country. For instance, taking up the white oak, we form the following general table.

Name.	Average diameter.	Per cent. decayed.	Per cent. dead.
White oak	26 inches.	16⅔+	5+

That is, the general average of the white oak timber throughout the Purchase shows a diameter of twenty-six inches, with sixteen and two thirds per cent. of the timber decayed.

Similar tables for the other principal timbers are as follows:

Name.	Average diameter.	Per cent. decayed.	Per cent. dead.
Liriodendron	29 inches.	13 nearly.	5+
Black oak.	22½ "	26 "	7½ about.
Post oak	20 " nearly.	16⅔	not 3.
Spanish oak.	22 " +	20+	8 nearly.
Hickories	22 "	3+	6+
Sweet gum	28¾ "	12½	4+
Red oak	21¾ "	25	7+
Bartram oak	30 "	25	not 7.

From these tables, it appears that the bartram oak has a larger average diameter than any other tree in this part of Kentucky, and liriodendron stands next to it. We should expect that, for the bartram oak is a large tree, and then it is never found, except in swamps and low places where the timbers are always larger than on uplands. Post oak has the smallest percentage of dead timbers, and next to it comes the sweet gum, followed by white oak and liriodendron, with the same percentages. Black oak stands first among decayed timbers, and bartram oak next. Hickories are by far the soundest timbers, and have a smaller percentage among their decayed than among their dead trees. It will be noticed, also, that as a rule, swamp timbers are sounder than upland timbers. This would have been expected.

From the tables already given, other series may also be produced. For instance, the following list shows the relative numbers of different timbers to be met with.

White oak, 121; bartram oak, 13; black oak, 54; liriodendron, 39; hickories, 32; post oak, 43. That is, there are one hundred and twenty-one white oaks to fifty-four black oaks, throughout the old forests, in this part of Kentucky, and so on. I do not think there is as much liriodendron timber as hickory in the woods; but the valuable liriodendron is more plentiful than the valuable hickory, as the table shows. Again, if we consider the timbers given in the "general average" tables above, to be all the forest timbers in the Purchase (and they are at least ninety per cent. of them), white oak forms about thirty-two per cent. of all the forest timbers, and black oak comes next, forming less than fifteen per cent. If the estimate of the value of the standing forests of the Purchase previously given be correct, the white oak alone now standing in this comparatively small strip of Kentucky, is worth from $3,000,000 to $5,000,000. It remains for the people, by prudence and forethought, to perpetuate a timber which is, in itself, a fortune to them.

SUMMARY.

A brief survey of the foregoing pages shows:

1. That there are vast bodies of valuable timbers lying along all the streams of the Purchase country, but that these streams are not well adapted for floating them out.

2. That as much as two thirds of the upland of this part of Kentucky is clothed with valuable timbers.

3. That there is not, at present, much drain upon the forests of the Purchase, and that not more than one two hundred and fiftieth of these forests is likely to be called for per annum, at any time, in the immediate future. At this rate they can easily reproduce themselves, with the exception of the white oak, which does not tend to perpetuate itself. Of course, the *available* timbers will be the ones drawn upon, and they would be exhausted in a few years, comparatively, at such a drain as I have considered possible in the future.

4. The white oak forms about thirty-two per cent. of the forest timbers in the Purchase, and, alone, would be worth, at Paducah, the enormous sum of $3,000,000 to $5,000,000. The total forests of the Purchase are estimated at from ten to fifteen millions of dollars in value.

CUPULIFERÆ—MASTWORTS.

1. *Genus Quercus.*
   - White oak, Quercus alba (L.)
   - Swamp white oak, Q. bicolor (Willd.)
   - Red oak, Q. rubra (L.)
   - Pin oak, Q. palustris (Mx.)
   - Spanish oak, Q. falcata (L.)
   - Black oak, Q. tinctoria (Bart.)
   - Post oak, Q. obtusiloba (Mx.)
   - Bartram oak, Q. heterophylla (Mx.)
   - Black-jack, Q. nigra (L.)
   - Laurel oak, Q. imbricaria (Mx.)
   - Swamp laurel oak, Q. Laurifolia (Mx.)
2. *Genus Castanea.*
   - Chestnut, Castanea vesca (L.)
3. *Genus Fagus.*
   - Common beech, Fagus sylvatica (L.)
   - Red beech, F. ferruginea (Ait.)
4. *Genus Ostrya.*
   - Hop hornbeam or ironwood, Ostrya virginica (Willd.)

JUGLANDACEÆ—WALNUT.

1. *Genus Juglans.*
   - Black walnut, Juglans nigra (L.)

2. *Genus Carya.*
   Shagbark hickory, Carya alba (Nutt.)
   Black hickory, C. tomentosa (Nutt.)
   Pignut hickory, C. glabra (Sorr.)
   White hickory, C. microcarpa (Nutt.)

ACERACEÆ—MAPLES.

1. *Genus Acer.*
   Red maple, Acer rubrum (L.)
   White maple, A. dasycarpum (Ehrh.)
   Sugar maple, A. saccharinum (L.)
   Black sugar maple, A. nigrum (Mx.)

CORNACEÆ.

1. *Genus Cornus.*
   Flowering dogwood, Cornus florida (L.)
   Low cornel, C. canadensis (L.)
2. *Genus Nyssa.*
   Black gum, Nyssa multiflora (Wang.)
   Swamp black gum, N. uniflora (Walt.)

BETULACEÆ—BIRCHWORTS.

1. *Genus Betula.*
   Red birch, B. nigra (Ait.)
2. *Genus Alnus.*
   Smooth alder, Alnus serrulata (Willd.)

OLEACEÆ.

1. *Genus Fraxinus.*
   White ash, Fraxinus Americana (L.)
   Black ash, F. sambucifolia (Lam.)
   Blue ash, F. quadrangulata (Mx.)

ULMACEÆ—ELMWORTS.

1. *Genus Ulmus.*
   Slippery elm (red elm), Ulmus fulva (L.)
   White elm, U. Americana (L.)
   Winged elm (whahoo), U. alata (Mx.)

ROSACEÆ.

1. *Genus Cerasus.*
   Black cherry, Cerasus serotina (D. C.)
2. *Genus Prunus.*
   Red and yellow plum, Prunus Americana (Mx.)
3. *Genus Cratægus.*
   Hawthorn, Cratægus oxycantha (L.)
   Red haw, Cratægus viridis.

SALICACEÆ—WILLOW-WIRTS.

1. *Genus Salix.*
   Willows—two or three varieties.
2. *Genus Populus.*
   Silver-leaf poplar, Populus alba (L.)

LEGUMINOSÆ.

1. *Genus Robinia.*
   Black locust, Robinia pseudacacia (L.)
2. *Genus Cercis.*
   Redbud (Judas tree), Cercis Canadensis (L.)

ANACARDIACEÆ.

1. *Genus Rhus.*
   Red sumach, Rhus glabra (L.)
   Black sumach, R. typhina (L.)

CAPRIFOLIACEÆ.

1. *Genus Viburnum.*
   Black haw, Viburnum prunifolium (L.)

PLATANACEÆ.

1. *Genus Platanus.*
   Sycamore, plane tree, Platanus occidentalis (L.)

LAURACEÆ—LAURELS.

1. *Genus Sassafras.*
   Common sassafras, Sassafras officinale (Nees.)

ARTOCARPACEÆ.

1. *Genus Morus.*
   Red mulberry, Morus rubra (L.)

BIGNONACEÆ—TRUMPET FLOWERS.

1. *Genus Catalpa.*
Catalpa, Catalpa bignonioides (Walt.)

MAGNOLIACEÆ.

1. *Genus Liriodendron.*
Tulip tree, Liriodendron tulipfera (L.)

ANONACEÆ.

1. *Genus Asimina.*
Common papaw, Asimina triloba (Dunal.)

HAMAMELACEÆ—WITCH HAZELWORTS.

1. *Genus Liquidambar.*
Sweet gum, Liquidambar styraciflua (L.)

EBENACEÆ.

1. *Genus Dyospyros.*
Persimmon, Dyospyros Virginiana (L.)

CONIFERÆ.

1. *Genus Taxodium.*
Bald cypress, Taxodium distychum (Rich.)

GEOLOGICAL SURVEY OF KENTUCKY.

N. S. SHALER, DIRECTOR.

CHEMICAL REPORT

OF THE

SOILS, COALS, ORES,

IRON FURNACE PRODUCTS, CLAYS, MARLS, MINERAL WATERS, ROCKS, ETC., OF KENTUCKY.

BY ROBERT PETER, M. D., ETC., ETC.,
CHEMIST TO THE SURVEY.

THIRD CHEMICAL REPORT IN THE NEW SERIES, AND THE SEVENTH SINCE THE BEGINNING OF THE KENTUCKY GEOLOGICAL SURVEY.

PART VII. VOL. V. SECOND SERIES.

STEREOTYPED FOR THE SURVEY BY MAJOR, JOHNSTON & BARRETT, YEOMAN PRESS, FRANKFORT, KY.

INTRODUCTORY LETTER.

CHEMICAL LABORATORY,
KENTUCKY GEOLOGICAL SURVEY,
LEXINGTON, KY., April, 1878.

Professor N. S. SHALER, *Director Kentucky Geological Survey:*

DEAR SIR: I have the honor to make herewith a report of the results of the chemical work performed for the Kentucky Geological Survey from February of last year up to the present time.

Very respectfully,

ROBERT PETER.

CHEMICAL REPORT OF THE SOILS, COALS, ORES, PIG IRONS, CLAYS, MARLS, MINERAL WATERS, ROCKS, &c., OF KENTUCKY.

Of the chemical analyses herewith reported, more than one hundred and thirty in number, seventy-four are of soils, subsoils, and under-clays; of which three, reported in the Appendix, are from Texas. These latter were examined for the purpose of comparison with our Kentucky soils.

The limits of variation, in the proportions of the essential ingredients of the seventy-one Kentucky soils, are shown in the following table, viz:

	Per ct.	Number.	County.	Per cent.	Number.	County.
Organic and volatile matters vary from . . .	9.185	in 2,037	in Hardin	to 2.045	in 1,986	in Allen
Alumina and iron and manganese oxides vary from	24.465	in 2,015	in Grant	to 3.096	in 2,029	in Grayson
Lime carbonate varies from	9.425	in 2,015	in Grant	to .030	in 1,968	in Allen
Magnesia varies from.	.824	in 2,022	in Grant	to .025	in 2,042	in Hardin
Phosphoric acid varies from.	.823	in 2,014	in Grant	to .013	in 1,968	in Allen
Potash extracted by acids varies from	1.778	in 2,022	in Grant	to .035	in 2,041	in Hardin
Soda extracted by acids varies from	.617	in 2,009	in Grant	to traces	in several	
Sand and insoluble silicates vary from	59.940	in 2,015	in Grant	to 92.980	in 1,967	in Allen
Water, expelled at 380° F., varies from . . .	2.715	in 2,037	in Hardin	to .483	in 2,030	in Grayson
Water, expelled at 212° F., varies from . . .	6.575	in 2,013	in Grant	to .950	in 1,967	in Allen
Potash, in the insoluble silicates, varies from .	2.910	in 2,037	in Hardin	to .722	in 1,979	in Barren
Soda, in the insoluble silicates, varies from . .	1.214	in 2,009	in Grant	to .022	in 2,080	in Oldham

In the sample of cretaceous soil from Collins county, Texas, called "black waxy" soil, there were 17.085 per cent. of lime carbonate, 0.497 of potash extracted by acids, while the 61.840 per cent. of sand and insoluble silicates contained only 0.443 per cent. of potash in the insoluble silicates.

The specimens from Grant county, which appear to such advantage in this comparative table, are of heavy, tough under-clays, excavated from some of the cuts on the Cincinnati Southern Railroad, some of which were called by the doubtful name of "hard pan" by the contractors. From the too large proportion of clay which they contain, as well as their resulting physical constitution, they would by no means prove as productive, under culture, as might be inferred from their chemical composition alone. The fact that favorable physical conditions are as necessary to the fertility of the soil as the chemical conditions, has long been known; but both the chemical and physical are equally indispensable.

These heavy under-clays, which are so rich in some of the mineral elements of plant nourishment, might doubtless be used with advantage, in the manner of marl, as a top-dressing on light or sandy, poor or exhausted soils. They would also answer for common pottery or bricks.

The five samples of *coals* examined, from Butler, Greenup, and Madison counties, presented the usual characteristics of our good Kentucky coals, some of them being better than the average, because of their small proportions of ash and sulphur, especially the sample from Big Hill, in Madison county.

The *limonite iron ores*, from Lyon and Trigg counties, proved to be rich, containing from 46.320 to 50.195 per cent. of iron; they are also remarkably free from sulphur, and contain less than the average of phosphorus, which latter ingredient was found in them only in the proportions of from 0.079 to 0.220 per cent. of the ore. The pig irons smelted from these ores were found also to be generally of very good quality.

Amongst the *clays* which were analyzed, that from Bald Knob Church, Ohio county—No. 2076—was found to be quite refractory, and it may very probably be made available for fire-clay if in sufficient abundance.

Seventeen different samples of *limestone* were examined, many of which were from the phosphatic layers in the blue limestone of Fayette county, mentioned in the preceding Report. In fourteen samples, mostly from the same quarry, and all from the same neighborhood, the proportions of phosphoric acid were found to vary from 1.462 per cent. in No. 2002 up to 21.940 per cent. in sample four of No. 2004. (See Fayette county.)

While these interesting phosphatic layers, in the Lower Silurian limestone of this county, have not as yet been found regular and continuous enough, perhaps, to justify working for

the manufacture of superphosphate, they are yet quite interesting, as throwing much light on the superior fertility of our Lower Silurian, or so-called "Blue-grass soil." As will be seen, the analyses of some of the most abundant of the fossils of this limestone did not develop in these any unusual proportion of phosphoric acid.

One of the limestones analyzed—No. 2073—a ferruginous limestone from Rough creek, Ohio county, was found, when calcined, to possess the properties of hydraulic cement.

The lead ore found in our limestone, usually associated with zinc sulphide in veins of baryta sulphate, examined for silver, was found to give the usual negative result. Indeed, general experience, hitherto, seems to show that very little silver is associated with the galena found in undisturbed limestone layers; that ore being most generally argentiferous which is in veins in the rocks which have been much disturbed by volcanic action.

The re-examination of the *mineral waters* of the Olympian Springs, in Bath county, and of the Lower Blue Lick Springs, in Nicholas county, has developed several interesting facts. Not only is it shown that the general composition of these celebrated waters has not been altered, or the waters weakened sensibly, during the considerable period intervening between the analyses, but also several new ingredients, in small quantities, have been discovered in them. Not the least interesting of these are boracic acid and lithium compounds. Compounds of barium and strotium found in these, also in minute proportions, are believed to be, like the above substances, more generally prevalent than was formerly supposed.

Several other mineral waters, deserving of a more complete examination, were qualitatively examined. Kentucky is quite rich in these waters, and a more systematic study of them than has, as yet, been possible, is desirable.

The chemical analyses of the *ashes* of the *Hungarian grass*, *German millet*, &c., together with the microscopic photographs of parts of their silicious skeletons by Mr. Alex. T. Parker and Mr. J. Mullen, and the experiments to discover the nature of the peculiar "root action" of these plants in their decomposition of the silicates of the soil, as well as to determine the nature of the special acid solvents exuded from the plants for this purpose, detailed in the Appendix, throw some light on the mysterious selective power of vegetables, by which materials, very different in kind and quantity, are appropriated by different plants from a soil common to all. Some, because probably of superior decomposing power which they exert over the silicates of the soil, being able to extract essential mineral ingredients and thrive, where others die of inanition, for want of the proper solvent or digestive agent.

To produce the silicious cell-casts and skeleton of the Hungarian grass and German millet, the silicious material must have been dissolved in water, in unusually large proportion, in the vicinity of the roots of these plants. Unless in solution, it could not penetrate the cell walls.

It is well known to chemists that when silicates are decomposed, by acids or other agents, in the presence of water, that the silicic acid thus produced is soluble to a large amount in that fluid; but that it may again be easily brought to an insoluble condition, as it exists in flint or sand, by the subsequent separation of the water; and this fact, with the demonstration of the exudation from the rootlets of these plants of an acid fluid containing oxalic, phosphoric, and other acids, probably in greater quantity than is produced by many other vegetables, enables us to guess how these may decompose more of the silicates of the soil than other plants and absorb more dissolved silicic acid.

Plants, like animals, vary greatly in their natural power of appropriating essential elements of food. Some live and thrive on food of most difficult digestion; others, like the young of most animals, require nourishment in the most soluble and available condition. Some, like the Hungarian grass and other plants which grow on sterile soils, can extract their essential mineral food from the hardest stony particles; others, like our ordinary grain-producing plants, depend more on the natural soil solution, which brings their food to their roots

already in a condition to be most readily absorbed. Peculiar root action on the soil is no doubt common, in a greater or less degree, to all plants; yet, that the common soil solution, produced by the solvent action of the atmospheric waters upon the soil ingredients, is also a common source of plant food, is equally demonstrable.

ALLEN COUNTY.

No. 1967—SOIL, *labeled "Virgin soil, from the surface of the tract of land of about fifty square miles in extent, in the eastern part of Allen county, called the 'Buncombe tract.' A very poor district. Forest growth: scrub oak, black oak, poplar, chestnut, hickory, &c. Produces about three to five barrels of corn to the acre (equal to fifteen to twenty-five bushels). Sub-stratum arenaceous, clayey, and calcareo-silicious rocks; decayed to the depth of fifteen feet." Collected by Rev. Herman Hertzer.*

The dried soil is of a light dirty-buff color. The coarse sieve removed from it only a few small ferruginous concretions. The silicious residue, after digestion in acids, all passed through fine bolting-cloth, except a small proportion of small rounded grains of quartz and undecomposed silicates, and a few very small silicified entrochi.

No. 1968—"SUBSOIL *of the next preceding soil," &c., &c. Collected by Rev. Herman Hertzer.*

Of a lighter and more yellowish buff color than the preceding; containing fewer small ferruginous concretions. The fine bolting-cloth separated from the silicious residue only a few small rounded grains of quartz and of undecomposed silicates of various tints.

No. 1969—"SURFACE SOIL, *one year in cultivation. Upland. Land of William H. H. Mitchell, one mile west of Scottsville, Allen county. Forest growth: a maple grove. Product: fifty to sixty bushels of corn to the acre." Collected by Rev. Herman Hertzer.*

The dried soil is of a light greyish-umber color. The coarse sieve removed from it a few angular fragments of ferruginous quartzose rock. The fine bolting-cloth separated from silicious residue a small quantity of fine rounded particles of quartz and undecomposed silicates of a reddish-grey color.

No. 1970—"SUBSOIL *of the next preceding,*" *&c., &c. Collected by Rev. Herman Hertzer.*

The dried subsoil is very much in color like the surface soil, being only slightly lighter. The coarse sieve and bolting-cloth removed similar fragments and particles from the soil and the silicious residue. The rounded particles of undecomposed silicates and quartz amounted to about four and a half per cent. of the subsoil.

No. 1971—"SURFACE SOIL. *Upland, from the farm of Wm. H. H. Mitchell (same locality as the preceding), which has been in cultivation for sixty years. Yields twenty-five bushels of corn per acre; eight to ten bushels of wheat; or fifteen to twenty of oats. Original forest growth: chestnut, maple, oaks, poplar, &c. Geological formation: the Keokuk Group—calcareo-silicious and argillaceous rocks and shales; decayed to the depth of twenty feet below the soil.*" *Collected by Rev. Herman Hertzer.*

The dried soil is of a buff color. The coarse sieve separated from it some small quartzose concretions, silicified entrochi, and iron gravel. The silicious residue, from the digestion in acid, all passed the fine bolting-cloth except a few rounded grains of milky quartz and of dark-colored undecomposed silicates, with some minute silicified entrochi.

No. 1972—"SUBSOIL *of the next preceding,*" *&c. Collected by Rev. Herman Hertzer.*

The subsoil is lighter and brighter colored than the surface soil. The coarse sieve removed from it fewer quartzose and ferruginous concretions than from that, and the bolting-cloth separated fewer silicious particles.

COMPOSITION OF THESE ALLEN COUNTY SOILS, DRIED AT 212° F.

	No. 1967.	No. 1968.	No. 1969.	No. 1970.	No. 1971.	No. 1972.
Organic and volatile matters	2.215	2.045	5.475	4.000	2.745	2.450
Alumina and iron and manganese oxides	3.616	5.872	5.629	7.394	5.452	8.090
Lime carbonate	.110	.030	.520	.470	.070	.080
Magnesia	.106	.097	.124	.097	.079	.140
Phosphoric acid	.019	.013	.156	.141	.083	.045
Sulphuric acid	Not esti	mated.				
Potash	.144	160	.148	.380	.221	.219
Soda	.489	.312	.210	.175	.143	.115
Sand and insoluble silicates	92.980	90.840	85.740	85.090	90.440	88.040
Water, expelled at 380° F.	.650	.615	2.200	1.625	.865	.850
Total	100.329	99.984	100.202	99.372	100.098	100.029
Hygroscopic moisture	0.950	1.250	2.425	2.215	1.175	1.550
Potash in the insoluble silicates	.992	.958	.958	.853	1.081	1.188
Soda in the insoluble silicates	.253	.209	.314	.242	.354	.258
Character of the soil	Virgin soil	Subsoil.	New soil	Subsoil.	Old field.	Subsoil.

The unproductiveness of the soils Nos. 1967 and 1968, from the so-called Buncombe tract, finds an explanation in their chemical composition as detailed above. Both surface soil and subsoil show a very marked deficiency of phosphoric acid, the proportions of which, 0.019 and 0.013 per cent. only, are smaller than have been found in any other Kentucky soils. This deficiency alone would cause sterility; but it fortunately can be remedied quite easily by means of top-dressings of fertilizers containing phosphates, such as commercial superphosphate of lime, bone-dust, or good guano. These soils are also somewhat deficient in organic matters (humus), lime, &c., and may no doubt be greatly improved by the cultivation of clover, with top-dressings of plaster of Paris or slaked lime, and the plowing under of the green crop after one year's grazing with hogs or cattle. The relative small proportion of alumina, &c., to the sand and silicates, which makes them what are called a "hungry soil," may be measurably remedied by the judicious use of such clay marls as may be accessible. The alkalies, potash, and soda are not greatly deficient in these soils, yet the use of wood ashes, or some other alkaline fertilizer, would doubtless increase their fertility.

The soils Nos. 1969–1970 and 1971–1972, differing so greatly in productiveness—soil 1969 producing fifty to sixty bushels of corn to the acre, and the others only twenty-five bushels—also exhibit very significant differences in their chemical composition. Taking the surface soils for comparison, we find the more productive soil, No. 1969, contains nearly twice as much organic matters and phosphoric acid as the less fertile one, No. 1971, and that this latter essential ingredient, phosphoric acid, is notably deficient in the less productive soils. Another marked difference is found in the relative proportions of lime and magnesia, the great deficiency of which in the old field soils seems to indicate that their present inferiority is probably as much owing to an original difference of composition as to the deteriorating influence of the sixty years of cultivation. This supposition is strengthened by the relatively higher proportion of potash in the old field soil.

The remarks on the improvement of the soil of the Buncombe tract apply also to this old field soil.

BARREN COUNTY.

Soils and Subsoils, &c.

No. 1973—"Virgin Soil, *from the farm of Major J. S. Barlow, in the 'Barrens,' four miles east of Cave City, Barren county." Collected by Rev. Herman Hertzer.*

"Geological formation: St. Louis limestone, the partly decomposed rock six feet beneath the surface. Very rich soil generally in the 'Barrens.' The 'Barrens,' so-called because of the absence of forest growth in early times, extend from Hardin county through Barren, Warren, and Simpson counties. Formerly 'prairie' land, now overgrown with a young forest of black oak, scrub oak, walnut, beech, and hickory."

The dried soil is of a light umber color. Clods friable. The coarse sieve removed from it only a small quantity of small fragments of decomposing chert and iron gravel. The silicious residue, after digestion in acids, all passed through fine bolting-cloth, except a small quantity of particles of partly decomposed silicates, and some few clear quartz grains.

No. 1974—"Soil, *sixty years in cultivation, from the same locality as the last. Average crops: of tobacco, one thousand*

two hundred pounds; wheat, fifteen bushels; corn, forty to fifty bushels." Collected by Rev. Herman Hertzer.

The dried soil is of an umber color, slightly darker than that of the preceding soil. The clods are friable. The coarse sieve separated from it about forty per cent. in weight of angular fragments of decomposing chert. The silicious residue all passed through the fine bolting-cloth, with the exception of some small angular particles of partly decomposed silicates.

[From the comparative color and chemical composition of these two soils, it is probable that their labels were accidentally interchanged.]

No. 1975—"Subsoil *of the two preceding soils," &c., &c.*

The dried subsoil is of a light grey-brown color; is somewhat cloddy, the clods being firm. The coarse sieve removed from it only a few small fragments of decomposing chert. The silicious residue, after digestion in acids, all passed through fine bolting-cloth, except some small particles of partly decomposed silicates, and a few small rounded quartz grains.

No. 1976—"Virgin Soil, *from the farm of Daniel Davasher, southern part of Barren county. Geological formation: silicious grit, decomposed fifteen feet deep. Forest growth: beech, hickory, oaks, poplar, and chestnut." Collected by Rev. Herman Hertzer.*

The dried soil is of a light brownish-grey color. The coarse sieve removed from it about twenty-two per cent. of coarse angular fragments of ferruginous sandstone and silicious concretions. The bolting-cloth separated from the silicious residue some silicious particles, grey, white, and flesh-colored, with a few of partly decomposed silicates.

No. 1977—"Surface Soil; *in cultivation for thirty years; from the same farm as the next preceding. Yield: of corn, forty bushels; of wheat, ten to fifteen bushels; of tobacco, eight hundred pounds." Collected by Rev. Herman Hertzer.*

The dried soil is of a light dirty-buff color. The coarse sieve removed from it about seven per cent. of coarse silicious fragments, and the silicious residue left on the fine bolting-cloth a few particles similar in character to those of the virgin soil.

No. 1978—"SUBSOIL *of the next preceding*," *&c.*, *&c.* *Collected by Rev. Herman Hertzer.*

The dried subsoil is of a grey-buff color. It contains about eleven per cent. of coarse angular silicious fragments and concretions, and its silicious residue gave fewer silicious particles by the fine bolting-cloth than the preceding.

No. 1979—"VIRGIN SOIL, *from the farm of Mrs. M. E. Davis, eight miles south of Glasgow, Barren county. Geological formation: silicious or Kekokuk Group. Forest growth: black walnut, beech, sugar-tree, &c., &c.*" *Collected by Rev. Herman Hertzer.*

The dried soil is of a light grey-umber color. The coarse sieve removed from it less than five per cent. of coarse angular silicious fragments and concretions. The silicious residue, from digestion in acids, all passed through the fine bolting-cloth, except small greyish, reddish, and white particles of quartz and partly decomposed silicates.

No. 1980—"SURFACE SOIL, *sixty years in cultivation; from the same farm as the preceding. Geological formation: silicious or Keokuk Group, rocks decayed to depth of twelve to fifteen feet. Average crops: of tobacco, one thousand to eleven hundred pounds; of corn, twenty-five to forty bushels.*" *Collected by Rev. Herman Hertzer.*

The dried soil is a little lighter colored and more yellowish than the preceding. The coarse sieve removed from it but a very small proportion of small angular silicious and ferruginous fragments, and the silicious residue contained fewer small silicious grains than the preceding.

No. 1981—"SUBSOIL *of the next preceding*," *&c.*, *&c.* *Collected by Rev. Herman Hertzer.*

The dried subsoil is of a brownish-buff color. The coarse

sieve separated from it only a very small proportion of small silicious and ferruginous gravel. The fine bolting-cloth removed from the silicious residue a considerable proportion of soft, partly decomposed silicate grains, and but few hard silicious particles.

No. 1982—"SURFACE SOIL, *sixty years in cultivation; from the same farm as the preceding. Bottom land. Inexhaustible because of annual inundation. Average crop: fifty bushels of corn.*" *Collected by Rev. Herman Hertzer.*

The dried soil is of a light brownish-umber color. The coarse sieve separated only a very small proportion of small silicio-ferruginous fragments, and the silicious residue, from digestion in acids, all passed through the fine bolting-cloth.

No. 1983—"SUBSOIL *of the next preceding*," *&c.*, *&c.* *Collected by Rev. Herman Hertzer.*

The dried subsoil is slightly more brownish in tint than the preceding. The coarse sieve removed from it but a very small proportion of silicio-ferruginous gravel. Like that of the preceding, the silicious residue all passed through the fine bolting-cloth, leaving upon it no small silicious particles.

COMPOSITION OF THESE BARREN COUNTY SOILS, DRIED AT 212° F.

	No. 1973	No. 1974	No. 1975	No. 1976	No. 1977	No. 1978	No. 1979	No. 1980	No. 1981	No. 1982	No. 1983
Organic and volatile matters	4.175	5.475	2.615	5.465	3.065	2.300	4.700	3.450	2.415	4.150	3.725
Alumina and iron and manganese oxides	7.365	7.740	8.323	4.310	4.942	6.142	4.632	4.622	6.186	5.967	6.034
Lime carbonate	.215	.465	.090	.340	.225	.125	.425	.190	.190	.475	.475
Magnesia	.197	.250	.197	.047	.065	.080	.061	.061	.065	.017	.115
Phosphoric acid	.125	.275	.092	.125	.093	.093	.108	.198	.124	.093	.131
Sulphuric acid	Not estimated.										
Potash	.209	.126	.308	.184	.158	.092	.069	.126	.225	.105	.161
Soda	. . .	.004	. . .	.029	.053	.055	.060	.024	.086	. . .	. . .
Sand and insoluble silicates	86.065	82.990	86.665	87.470	90.185	89.985	87.985	89.685	89.650	87.710	87.835
Water, expelled at 380° F.	1.575	2.275	.935	1.800	1.015	.800	1.650	1.300	1.000	1.325	1.375
Total	99.926	99.600	99.225	99.770	99.801	99.672	99.690	99.656	99.941	99.842	99.851
Hygroscopic moisture	1.865	2.500	1.775	2.150	1.500	1.700	2.100	1.650	1.735	1.800	1.900
Potash in the insoluble silicates	1.227	1.074	1.253	.934	1.102	1.179	.722	1.223	1.151	1.156	1.127
Soda in the insoluble silicates	.394	.334	.373	.300	.318	.256	.234	.381	.318	.372	.446
Character of the soil	Virgin.	Old field	Subsoil.	Virgin.	Old field	Subsoil.	Virgin.	Old field	Subsoil.	Old field	Subsoil.

The reasons for believing that the labels of soils Nos. 1973 and 1974 have been accidentally interchanged, is the greater proportions of organic matters, lime, magnesia, and phosphoric acid, and the smaller quantity of sand and insoluble silicates in 1974 than in 1973. The greater proportion of potash in the latter is also corroborative of this supposition because the subsoil is richer in this alkali than the surface soils.

These Barren county soils are above the average in native fertility, and would require only skillful management, with a judicious rotation of crops and the occasional use of special fertilizers, as may be indicated, to keep them up to a high degree of productiveness.

BATH COUNTY.

MINERAL WATERS, &c., OF THE OLYMPIAN SPRINGS.

The principal waters of these celebrated springs were qualitatively examined by the writer about the year 1848–'9, and the results were published in volume III of the first series of Reports of the Geological Survey of Kentucky, pages 208–210. About ten years thereafter (in 1858–'9) more extended quantitative analyses were made by him of samples of these waters, sent to his laboratory in bottles by Mr. H. Gill, the proprietor. As such analyses of the waters forwarded in bottles could not include the gases, and, moreover, were liable to accidental errors, the writer visited these springs in August last (1877), accompanied by his son, Alfred M. Peter, in order to quantitatively estimate the gases in the recent waters; to evaporate a sufficient quantity on the spot to enable him to estimate their minuter saline ingredients, and to collect with care, in very clean glass-stoppered bottles, enough of the waters of the several springs for complete quantitative analyses in his laboratory in Lexington.

The hydrogen sulphide was estimated in the recent waters at the springs, by the volumetric process, with the use of a deci-normal iodine solution, &c., and the carbonic acid, thrown down in a measured quantity of the waters, by an ammoniacal solution of barium chloride, was separated and weighed at the laboratory.

THE SULPHUR WATERS OF THE OLYMPIAN SPRINGS.

NO. 1984—"SALT SULPHUR WATER." *Well at the saloon, near the main house or hotel. The water is raised by a pump in the well, which is eight to ten feet deep. The spring is said to yield about two hundred and seventy gallons per hour. The temperature of the water was found to be 56° F., when that of the atmosphere was 75° F. The water forms a slight yellowish or ochreous incrustation on the glass tumblers used at the well. It exhibits a slightly alkaline reaction.*

NO. 1985—"BLACK SULPHUR WATER." *From an open well, about a quarter of a mile nearly south of the main house, in the bottom ground just at the foot of the hill. The water is confined in a barrel without heads, sunk into the ground. The temperature of the water in the barrel was 57° F. Its sediment is nearly black, and it exhibits a slightly alkaline reaction.*

NO. 1986—"WHITE SULPHUR WATER." *From a rather feeble spring about three miles from the Olympian Springs.*

This spring was not visited by the writer, but a demijohn of the water was sent to the "Springs" by John D. Young, Esq. The hydrogen sulphide, therefore, was not estimated.

COMPOSITION OF THESE BATH COUNTY SULPHUR WATERS.

In 1000 parts of the water.

	No. 1984.	No. 1985.	No. 1986.	
Hydrogen sulphide gas	0.0011	0.0012	not est.	
Carbonic acid gas (CO_2)	0.2400	.2781	not est.	
Lime carbonate	0.1975	0.0158	0.0744	
Magnesia carbonate	.0506	.0046	.0316	
Baryta carbonate	.0128	. . . . .	. . . . .	
Strontia carbonate	.0045	. . . . .	. . . . .	Held in solution by the carbonic acid.
Iron carbonate	.0025	.0024		
Alumina	.0006	. . . . .	.0021	
Manganese carbonate and phosphoric acid	traces.	traces.		
Lime sulphate	.0083	.0061	.0039	
Potash sulphate	. . . . .	.0031	.0133	
Soda sulphate	. . . . .	.0025	.0408	
Soda carbonate. . . . . traces	not est.	.3247	.3113	
Calcium chloride	.0213	. . . . .	. . . . .	
Magnesium chloride	.1089	. . . . .	.0071	
Sodium chloride	4.8997	.1208	.1326	
Potassium chloride	.0355	. . . . .	. . . . .	
Lithium chloride	.0008	trace.	trace.	
Sodium bromide	.0166	. . . . .	. . . . .	
Sodium iodide and sulphide	trace.	trace.	trace.	
Boracic acid	trace.	trace.	trace.	
Silica	.0232	.0124	.0115	
Traces of organic matter and loss,	.0340	.0164	. . . . .	
Total saline matters in 1000 parts	5.4168	0.5088	0.6286	
Specific gravity of the water	1.004	not est.	not est.	

These interesting sulphur waters present considerable differences in their chemical composition. The salt sulphur of the saloon contains greatly more chlorides than the others, and especially much more sodium chloride (common salt) than they, while the black and white sulphurs are much more alkaline from the presence of a considerable quantity of carbonate of soda. They also contain more alkaline sulphates. All of them have a notable quantity of iron carbonate, of which chalybeate ingredient the salt sulphur and the black sulphur contain the largest proportions. The quantity in the white sulphur was not separately determined, but is doubtless quite minute.

These waters, and particularly those of the salt sulphur well, are applicable to the treatment of a great variety of chronic diseases, under judicious medical advice, combining, as they do, saline, alkaline, and chalybeate properties, with those of the hydrogen sulphide, and the bromides and iodides. They are found to be diuretic, diaphoretic, tonic, and alterative, when used internally, not usually exerting much aperient action; and when employed in the bath, for which purpose the salt sulphur is used exclusively, they are valuable in the treatment of cutaneous affections, &c.

The very small proportions of barium, strontium, aluminum, and lithium compounds, together with those of boracic and phosphoric acids, which were detected in this recent re-examination of these waters, interesting as their discovery may be to the philosopher, cannot be supposed to exert much influence in their medicinal action, yet, doubtless, they are not without effect.

Since the detection of barium and strontium compounds in these waters containing sulphates, the attention of the writer was drawn to a recent communication of M. Dieulafait to the Academy of Science of Paris, as to the very general presence of strontium carbonate or sulphate in the sea waters, as well as in limestone, gypsum, and the fossil remains of the mollusca, and saline mineral waters generally. According to his statement, only forty-four out of eight hundred of such waters, &c., failed to show distinct evidence of the presence of strontium.

On examining Liebig's analysis of the celebrated *Keiserquelle* (Emperor well), at Aix-la-Chapelle, in Rhenish Prussia, one of the most noted waters of Europe, and an early resort of the Romans, a remarkable resemblance in general composition may be seen between this and the salt sulphur water of the Olympian Springs, as the following comparative table shows:

	Salt sulphur water of Olympian Springs.	Water of Emperor Well, Aix-la-Chapelle.
Lime carbonate	0.1975	0.1580
Magnesia carbonate	.0506	.0510
Baryta carbonate	.0128	. . . .
Strontia carbonate	.0045	.0002
Iron carbonate	.0025	.0096
Alumina	.0006 }	traces.
Manganese, phosphoric acid	traces. }	
Lime sulphate	.0083	traces.
Potash sulphate	. . . .	.1540
Soda sulphate	. . . .	.2830
Soda carbonate	traces.	.6500
Lithia carbonate	. . . .	.0003
Lithium chloride	.0008	. . . .
Calcium chloride	.0213	. . . .
Magnesium chloride	.1089	. . . .
Sodium chloride	4.8997	2.6390
Potassium chloride	.0355	. . . .
Sodium bromide	.0166	.0036
Magnesium bromide	. . . .	.0006
Sodium sulphide	traces.	.0195
Sodium iodide	traces.	traces.
Boracic acid	traces.	. . . .
Silica	.0232	.0661
Organic matters, &c.	.0340	.0752
Total saline matters in 1000 parts	5.4168	4.1020
Temperature	56° F.	131° F.

The Aix-la-Chapelle are hot springs, and the water contains more alkaline sulphates and carbonates, with less of chlorides and bromides, than our salt sulphur water; but the general resemblance of their chemical composition is close, especially as they contain nearly the same gaseous ingredients.

One object in view in the re-examination of the Olympian Spring waters was to ascertain whether their proportion of saline matters had been diminished in the lapse of nearly twenty years since the first analyses were made by the writer. It is interesting to see that no notable change in this respect has occurred. (*See vol.* 4, *p.* 69, *Reports Geological Survey of Kentucky, first series*). The slight apparent difference being probably due to less perfect drying of the total saline matters in the former analyses.

CHALYBEATE MINERAL WATERS OF THE OLYMPIAN SPRINGS

No. 1987—"MAIN CHALYBEATE SPRING; *in a valley, about half a mile north of the main building, Olympian Springs.*"

The water runs, over a wooden gutter, out of the ferruginous magnesian limestone, which lies under the Devonian shale, at the base of the hill, about four feet above the bed of the so-called "Chalybeate Branch," which runs into Mud Lick. The spring yields about three litres of water per minute (*i. e.*, somewhat more than three quarts). The temperature of the water is 54° Fahrenheit. It deposits a sediment in its channel of outflow, which is of a ferruginous-brown color. The water, as it flows out of its source, is remarkably clear, but exposure to the air, by the removal of carbonic acid and the substitution of oxygen, converts the dissolved iron carbonate into the hydrated peroxide, which is insoluble in water.

The dried *ferruginous sediment*, on analysis, was found to contain about 65 per cent. of *iron peroxide*, about 20 per cent. of *soluble silica*, with notable proportions of *lime* and *magnesia carbonates*, and traces of *manganese*, *phosphoric* and *apocrenic acids*. Hydrosulphuric acid did not detect the presence of arsenic or any metal of that group.

No. 1988—"CHALYBEATE SPRING, *flowing out of a crevice in the ferruginous magnesian limestone in the bed of the Chalybeate Branch, about sixty yards above the main chalybeate spring above described.*"

It deposits a ferruginous sediment in the bed of the branch of a light brownish-orange color.

COMPOSITION OF THESE OLYMPIAN SPRING CHALYBEATE WATERS.

In the 1000 parts.

	No. 1987	No. 1988.	
Free carbonic acid gas	0.1214	0.1269	
Iron carbonate	0.0242	0.0100	Held in solution by the free carbonic acid.
Lime carbonate	.0998	.0890	
Magnesia carbonate	.0143	.0103	
Manganese carbonate	trace	trace.	
Phosphoric acid	trace.	trace.	
Lime sulphate	.0554	.0366	
Magnesia sulphate	.1170	.0693	
Potash sulphate	.0125	0117	
Soda sulphate	. . . .	.0238	
Sodium chloride	.0308	.c060	
Magnesium chloride	.0031	. . . .	
Lithium chloride	trace.	trace.	
Apocrenic acid	trace.	trace.	
Silica	.0332	.0198	
Loss	.0194	.0168	
Total saline matters in 1000 parts of the waters	0.4097	0.2935	

The main chalybeate spring water is in every respect very good of its kind, and may be used in all cases in which chalybeate remedies are indicated. The principal difference in composition between the two springs is, that the main spring is more than twice as strong in iron carbonate, making it a better chalybeate remedy than the other. It also contains more sulphate of magnesia, but less sulphate of soda. They form a valuable addition to the Olympian Springs.

As the chalybeate and other saline ingredients of these waters seem evidently to have been derived mainly from the ferruginous magnesian limestone out of which they flow, and which the waters have worn and perforated in a remarkable manner, the writer collected some of the limestone and submitted it to analysis, with the following result:

No. 1989—FERRUGINOUS MAGNESIAN LIMESTONE, *out of which flow the chalybeate springs above described, as well as many others in this region, and which forms the bed of the Chalybeate Branch, at and near those chalybeate springs. It lies immediately under Black Devonian Shale. Collected by Robert Peter.*

A crystalline granular limestone; grey, of various tints, in the interior—generally light grey; light ferruginous or brownish-ochreous on the exterior. Adheres slightly to the tongue, and is more or less porous. The water has worn it irregularly, and in some places perforated it by enlarging the small crevices or cavities in it.

COMPOSITION, DRIED AT 212° F.

Lime carbonate	54.000
Magnesia carbonate	34.027
Iron carbonate	11.532
Phosphoric acid	.006
Potash	.143
Soda	.040
Silica	.280
Total	100.028

The main agent in the solution of this ferruginous limestone is, undoubtedly, the carbonic acid dissolved in the water which flows over or percolates it. The greater part of this carbonic acid is no doubt derived from the gradual decomposition of the vegetable matters on the surface of the hill at the base of which the springs and this rock are located. At present this and the neighboring hills are covered with the primeval pine forest, which keeps the surface continually covered with its vegetable *débris*, which, by slow decomposition and oxidation, yields an abundance of carbonic acid to the atmospheric water which falls upon it, thus making it, what the pure water itself is not, a good solvent of the iron and other carbonates of the ferruginous magnesian limestone beneath. It appears, therefore, that the character or strength of these springs is greatly dependent on the forest growth on the surface of the hill or hills above them; and that if these woods on the hills above should be at any time cleared off, and the surface of the land deprived of its present carpet of decaying vegetable matters, the springs would measurably lose their strength and value. Another deplorable result from clearing off these woods and bringing the soil into arable culture would be, that more of the atmospheric water would run off from the surface of the hills, and less of it would sink into the depth of the soil and

subsoil to feed springs; so that, if the springs were not entirely dried up, except in a rainy season, their outflow would be greatly diminished. Moreover, the beauty, salubrity, and attractiveness of this favorite sylvan watering-place depend greatly on the native pine forest which clothes the neighboring hills.

In addition to the sulphur, salt sulphur, and chalybeate waters of this locality, there are others, saline and alkaline, of various qualities, deriving their dissolved ingredients, some from the salts of the primeval ocean under which the rocks were deposited, some from the action of the atmospheric waters and gases on the Devonian and other strata. One of the oldest known, which formerly was called a salt lick, to which the wild denizens of the forests resorted, and around which the buffaloes made their wallows, may be described as follows:

No. 1990—"SALT WATER *from the old well at the original Salt Lick, near the remains of the old barracks of the volunteers of* 1812, *about one hundred to one hundred and fifty yards south from the main house.*"

The water flows out in a small stream, running into Mud Lick creek. The ground about is covered with an efflorescence of salt. The water tastes like that of the salt sulphur well, but it has only a slight odor of hydrogen sulphide.

COMPOSITION OF THIS SALT WATER.

Carbonic acid gas, not estimated; hydrogen sulphide, a trace. In 1000 parts of the water.

Lime carbonate	0.1844	Held in solution by the carbonic acid.
Magnesia carbonate	.0458	
Baryta carbonate	.0099	
Strontia carbonate	.0045	
Iron and manganese carbonate, and phosphate	.0019	
Lime sulphate	.0036	
Soda carbonate	.2241	
Calcium chloride	.0152	
Magnesium chloride	.1188	
Sodium chloride	4.7121	
Potassium chloride	.0375	
Lithium chloride	trace.	
Bromine, boracic acid	trace.	
Silica	.0232	
Loss	.0130	
Total saline contents in 1000 parts of the water	5.3940	

This water resembles that of the salt sulphur well in the relative proportions of its common salt and other chlorides; but it is more decidedly alkaline, because of its larger proportion of carbonate of soda, and contains less of bromine and lithium compounds. Moreover, it is almost destitute of hydrogen and sodium sulphides, which give a distinctive character to the salt sulphur water. On examining volume IV of the Reports of the Geological Survey of Kentucky, first series, for the former analysis of this water, the writer finds that a transposition of the labels on the bottles in which the waters were sent to the laboratory by Mr. Gill must have occurred (see pages 71, 72), so that the label "salt water," &c., &c., was placed on the bottle which contained the so-called "cooking water," and *vice versa*. The analysis No. 803, page 72, agrees pretty well with the present in the principal ingredients and the total saline contents. This now published is of course more complete and accurate.

THE ALKALINE SALINE WATERS OF THE OLYMPIAN SPRINGS.

No. 1991—WATER *from the well at the kitchen door of the main house; about eight feet deep; yields about one hundred and thirty-five gallons per minute. The water is raised with a wooden pump.*

It is slightly alkaline in reaction, and deposits a slight ochreous sediment in the bottle. Tastes somewhat chalybeate, and smells and tastes faintly sulphurous. This water is used for all ordinary purposes of the kitchen and household, as well as for drinking.

No. 1992—WATER, *called "Tea Water," from a spring or open shallow well, on the border of Mud Lick creek, about half a mile south of the main house, and above it on the stream.*

The spring is inclosed in two no-headed barrels, placed the one on top of the other, and is about four feet deep. The water was not overflowing. Temperature of the water, 62°. Reaction slightly alkaline. As there had been rain shortly before the sample of the water was obtained for analysis, it may possibly be weaker than usual.

COMPOSITION OF THESE WATERS.

In 1000 parts of the water.

	No. 1991.	No. 1992.	
Carbonic acid gas	not est.	not est.	
Hydrogen sulphide gas	a trace.	none.	
Lime carbonate	0.0556	0.0241	Held in solution by carbonic acid.
Magnesia carbonate	.0277	.0059	
Strontia carbonate or sulphate	trace.	trace.	
Iron and manganese carbonates and phosphates	.0054	.0022	
Lime sulphate	.0065	.....	
Soda sulphate	.0208	.....	
Potash sulphate	.0285	.....	
Sodium chloride	.1483	.0377	
Potassium chloride	.....	.0039	
Magnesium chloride	.0047	.....	
Soda carbonate	.5431	.4479	
Sodium sulphide	trace.	.....	
Lithia, boracic acid	trace.	trace.	
Silica and loss	.0280	.0315	
Total saline contents in 1000 parts	0.8686	0.5532	

Although these waters do not contain a very large proportion of saline matters, yet their alkaline and slightly chalybeate properties may make them available as diuretic, depurative, tonic, and alterative remedial agents. Many celebrated alkaline waters are not stronger in saline and gaseous contents than these. These examinations and analyses were made in August, 1877; on reëxamining the water from the well at the kitchen door, No. 1991, in February, 1878, after rather a wet season, the water was found to be at least one third weaker in saline contents.

No. 1993—"WATER, *from an 'Epsom Well,' about three quarters of a mile northeast of Olympian Springs, on the farm of Mr. Robinson.*"

The well is about twenty feet deep, walled up with stone. The water is used by the family for drinking and all domestic purposes, and they have become accustomed to it, so that it produces no sensible effect upon them. Mr. Robinson had turned the rain water from the roofs of his houses into the well, so that the water obtained for examination had been much weakened by the result of a recent rain; hence a quantitative analysis was not made of it. It tasted strongly of Epsom salt, and gave decided evidence, by the usual tests, of the presence in it of much *magnesia* and *sulphuric acid*, considerable *lime* and *chlorine*, and traces of *iron*, &c., &c.

The old "Epsom Well," the water of which had been analyzed and reported by the writer in volume IV, page 70, of Reports of the Geological Survey of Kentucky, first series, had been filled up; but Mr. Robinson will probably reopen it. This aperient water would be a valuable addition to the considerable variety of the mineral waters of the Olympian Springs, especially as the other waters do not generally exert a laxative action.

BRECKINRIDGE COUNTY.

No. 1994—"MARLY SHALE, *from Tar Creek Hill; Bowling Green road, near Cloverport, Breckinridge county.*" *Collected by P. N. Moore.*

A friable shale; of a yellowish olive-grey color; containing many minute specks of mica. Before the blow-pipe it fuses into a dark colored slag. Burns of a handsome bright brick color.

COMPOSITION, DRIED AT 212° F.

Silica	66.960
Alumina	15.626
Iron oxide	8.380
Lime	.493
Magnesia	.677
Phosphoric acid	.154
Potash	3.295
Soda	.628
Water, carbonic acid, and loss	3.787
Total	100.000

This marly shale would no doubt be useful as a fertilizer on old exhausted soils of a light and sandy nature. Exposed to the frosts on the surface of the ground, it would very probably undergo complete disintegration. Its considerable proportion of potash would gradually become available for vegetable nourishment under the influence of the atmospheric

agencies, but might perhaps be brought more quickly into use by the simultaneous application of slacked lime on a clover crop. It might be used for *terra cotta*.

BUTLER COUNTY.

No. 1995.—"COAL *from 'Mining City Coal Bank,' recently opened; owned by the Green and Barren River Navigation Company. Mouth of Mud Creek. Bed thirty-six to thirty-nine inches thick. Average sample.*" *Sent from Frankfort by John R. Procter.*

A pure-looking coal, breaking into thin laminæ, with fibrous coal and very little fine-granular pyrites between. Specific gravity not determined.

COMPOSITION, AIR-DRIED.

Hygroscopic moisture	3.28
Volatile combustible matters	44.20
Spongy coke	52.52
Total	100.00
Total volatile matters	47.48
Fixed carbon in the coke	48.56
Dark lilac-grey ash	3.96
Total	100.00
Percentage of sulphur	3.060

A very good splint coal, resembling the "block coal" of Indiana, yielding quite a small proportion of ash, and containing no inordinate quantity of sulphur.

No. 1996.—"MARLY CLAY SHALE OR INDURATED CLAY. (*Fire-clay?*) *Below the coal at the Mud Creek Mines. Collected by John R. Procter.*"

Of a dark-grey or lead color, imperfectly and irregularly laminated. Contains many minute specks of mica, and some imperfect impressions, apparently of marine shells. It is quite plastic when powdered. Burns of a light yellowish-grey color, nearly white, hence might be made available in *terra cotta.* Fuses before the blow-pipe.

COMPOSITION, DRIED AT 212° F.

Silica	51.660
Alumina	15.560
Iron oxide	7.680
Lime	7.269
Magnesia	.817
Phosphoric acid	not est.
Potash	3.276
Soda	.293
Water, carbonic acid, organic matters, and loss	13.445
Total	100.00

Its large proportions of iron oxide, lime, and alkalies render it easily fusible at a high temperature.

FAYETTE COUNTY.

No. 1997.—"WATER *from a bored well about* 80 *to* 96 *feet deep, on the site of the Lexington Depot of the Cincinnati Southern Railroad, about three quarters of a mile from the Court-house.*" *Collected by Mr. C. J. Norwood and Mr.* ——— *Totten, Civil Engineer.*

The water is perfectly limpid and colorless, has a slight petroleum-like odor, but contains no hydrogen sulphide.

No. 1998.—"WATER *from the same well after it had been deepened to one hundred and fifty-three feet and a half. Sent by Chas. A. Tasker, Resident Engineer on the C. S. R. R., at Lexington.*"

The water is yet clear, inodorous, and tasteless; like the former sample, it gave a slightly alkaline reaction.

The object of the analyses was to ascertain the availability of this water for use in boilers of the locomotives of the railroad.

COMPOSITION IN 1000 PARTS OF THE WATER.

	No. 1997.	No. 1998.	
Lime carbonate	0.0404	0.0358	Held in solution in the water by carbonic acid, the proportion of which was not estimated.
Magnesia carbonate	.0066	.0189	
Silica	.0138	.0058	
Iron oxide, phosphoric acid, strontia carbonate	trace.	. . . . .	
Lime sulphate	.0126	.0240	
Potash sulphate	.0118	.0205	
Soda sulphate	.0385	.0058	
Magnesium chloride	.0097	.0501	
Sodium chloride	.0514	.0612	
Soda carbonate	.1252	.1530	
Silica	.0218	.0036	
Lithia, Organic matters	trace.	. . . . .	
Total saline matters in 1000 parts	0.3318	0.3787	

The water became very slightly stronger in saline matters by deepening the well, but its character was not materially altered. From its alkaline nature, owing to the presence in it of a certain proportion of carbonate of soda, the writer predicted that it would prove eminently fit for use in the steam-boiler, and that any sediment which might be deposited would not be likely to form a hard incrustation. Subsequent practical experience has verified this prediction. The material in the supply water which causes the hardest and worst crust in the steam-boiler is the lime sulphate or gypsum; as this is only slightly soluble in water, and is much less soluble in the very hot water of the high-pressure boiler than it is in cold water, its presence in the feed-water is greatly feared by the locomotive engineer. This injurious substance dissolves in about five hundred parts of cold water; but when subjected to the heat corresponding with four atmospheres of pressure in the steam-boiler, or one hundred and twenty pounds to the square inch, it deposits a crust, although contained in 1000 parts of water.

In the stronger of these waters the sulphate of lime is only in the proportion of about one part to forty thousand of the water; and, consequently, it would not probably form any crust until the water was evaporated to one fortieth its original volume, even if unaccompanied by any decomposing agent. But in this water, as soon as the free carbonic acid is separated by the heat, the excess of carbonate of soda present decomposes the sulphate of lime, producing a powdery precipitate of carbonate of lime, and an equivalent amount of sulphate of soda, which remains dissolved in the water. Perfect immunity from boiler-crust may generally be secured by blowing off the residual water of the boiler at proper intervals, varying in length according to the character of the water used.

In this connection, it may be of interest to give the elevation of this well above sea level, as communicated by Geo. B. Nicholson and Chas. A. Tasker, civil engineers on the Cincinnati Southern Railroad, as follows:

Elevation of the top of this well above sea level, 964 feet.

Elevation of the bottom of the bore which furnished the water for the first analysis, 876 feet.

Elevation of the bottom of the bore which furnished that for the second analysis, 802 feet.

Elevation of the top of the well at the Lexington fair grounds above sea level, 974 feet 3 inches.

SOILS OF FAYETTE COUNTY.

No. 1999—"SURFACE SOIL, *from the lawn at Ashland, near Lexington, homestead of the late Henry Clay, near Lexington, Kentucky.*" *Collected by John H. Talbutt.*

The dried soil is of a dark brownish-umber-grey color. It all passed through the coarse sieve except numerous rootlets and some small, friable, shot iron ore. It appears to contain no sand. The silicious residue from two grammes, left after digestion in acids, all passed through fine bolting-cloth except a single small grain of clear quartz, and some small, soft, rounded particles of partly decomposed silicates.

No. 2000—"SUBSOIL *of the next preceding,*" *&c., &c.*

The air-dried subsoil is a little lighter colored and more brownish than the surface soil. The clods are somewhat more adhesive. It contains a considerable proportion of fria-

ble shot iron ore. The silicious residue gave a single minute grain of transparent quartz only, when passed through the fine bolting-cloth.

COMPOSITION OF THESE FAYETTE COUNTY SOILS, DRIED AT 212° F.

	No. 1999.	No. 2000.
Organic and volatile matters	4.325	3.535
Alumina and iron and manganese oxides	12.168	15.666
Lime carbonate	.295	.345
Magnesia	.214	.331
Phosphoric acid	.492	.604
Sulphuric acid	not est.	not est.
Potash	.268	.372
Soda	.038	.....
Sand and insoluble silicates	80.090	77.715
Water, expelled at 380° F.	1.800	1.300
Total	99.690	99.868
Hygroscopic moisture	2.850	3.375
Potash in the insoluble silicates	1.343	1.273
Soda in the insoluble silicates	.359	.332
Character of the soil	Surface soil	Subsoil.

These present all the characteristics of our rich "bluegrass" or blue limestone soils. In the first place, they contain no gravel, pebbles, coarse sand, or even what might generally pass for fine sand, the whole being in such a state of fine division that, when the soft clods are disintegrated, by the action of water or otherwise, it will pass through fine bolting-cloth; yet, because of the presence of more than three fourths of its weight of exceedingly fine silicious material, water does not lodge on it, but readily passes through it, so that it is easily drained; and, because of the clefts and crevices in the limestone sub-stratum, it is usually naturally drained through the numerous subterraneous caverns and channels of the rock on which it rests.

These soils, moreover, present more than the usual proportion of phosphoric acid, and large proportions of the alkalies, potash, and soda, which aid in giving to them a very durable fertility. The proportions of alumina and iron oxide, of humus, &c., are such as characterize our richest soils.

PHOSPHATIC LAYERS IN THE LOWER SILURIAN LIMESTONE OF FAYETTE COUNTY.

In volume IV, new series, of Reports of the Geological Survey of Kentucky, on pages 65 and 66, mention is made and the analysis given, of a specimen of phosphatic limestone extraordinarily rich in phosphoric acid. As the quarry from which it came was not then in use, and the face of it had been covered by fallen earth, the correctness of the statement of the quarryman, to the effect that a layer of similar material was sometimes as much as a foot in thickness in this quarry, could not at that time be easily tested.

Other specimens of rock of similar external qualities, from the neighborhood of this quarry, were examined; and when the quarry was again opened and worked for turnpike material, in the autumn of 1877, a more complete examination was made by the writer, the results of which are given below.

No. 2001—"PHOSPHATIC LIMESTONE, *a layer in the Lower Silurian 'Blue Limestone' formation; taken from a shallow well at the Wine House at Winton, farm of Robert Peter, about six and a half miles north from Lexington, on the Newtown Turnpike. Collected by R. Peter.*"

In thin fissile layers, of a dark olive-slate color, between the harder, greyish-blue, more crystalline limestone layers. It contains many minute fossils, especially spiral shells.

No. 2002—"PHOSPHATIC LIMESTONE, *from a quarry on the farm of John Keiser, on the north side of the Newtown Turnpike, about six miles from Lexington. Collected by R. Peter.*"

Sample taken from the roadside, where it had been placed for turnpike purposes. It is of a dull, bluish-slate color, and is quite fissile. It does not contain so many small fossils as the next preceding.

COMPOSITION OF THESE PHOSPHATIC LIMESTONES, DRIED AT 212° F.

	No. 2001.	No. 2002.
Lime carbonate	78.040	57.440
Magnesia carbonate	2.332	7.327
Alumina and iron and manganese oxides	4.017	8.716
Phosphoric acid	2.623	1.462
Silicious residue	9.891	21.784
Alkalies, sulphuric acid, water, &c., &c.	3.097	3.271
Total	100.000	100.000

No. 2003—"PHOSPHATIC LIMESTONE, *from the same quarry, on the northwest side of the Newtown Turnpike, about three miles north of Lexington, from which the very rich specimen was taken described on pages* 65 *and* 66 *of the* 4*th volume, new series, of Kentucky Geological Reports. Collected by Robert Peter.*"

Taken from irregular layers, about one foot in thickness, near the base of the quarry, say from four to six feet below the surface of the rock, which is covered with about four feet of earth, on the ridge or hill in which the quarry is located. These layers are of a dark-grey color, of various thickness, mixed more or less with lighter-grey crystalline layers. The dark-grey portion adheres strongly to the tongue, absorbs water freely; it is quite tough in the mass, but somewhat friable in the small fragments, and contains small organic remains, principally fragments of brachiopod shells, some small gasteropods, and occasionally fragments of trilobite crusts.

COMPOSITION, DRIED AT 212° F.

Lime carbonate	49.160	
Magnesia carbonate	.090	
Phosphates, with alumina, iron oxide, &c.	46.540	Containing 21.018 phosphoric acid.
Silicious residue	2.820	
Organic matters and loss	1.390	
Total	100.000	

As it was evident, from the analyses already made, that the phosphoric acid was quite irregularly diffused throughout these irregular layers, eleven several samples were selected from portions of this phosphatic layer which had been quarried and hauled out to be broken up for the turnpike, described as follows, viz:

No. 2004—SPECIMEN 1*a*.—A somewhat crystalline layer, about one and three quarters inch thick, of a dull bluish-grey color; attached to layer 1*b*, which was darker colored (lead colored), more dull, and less crystalline than 1*a*.

SPECIMEN 2 is probably a continuation of 1.

SPECIMEN 3, probably a continuation of the same combined layer, contained a portion of a trilobite shield, which was not included in the portion analyzed.

SPECIMEN 4.—A thin layer, weathered of a light buff color.

SPECIMEN 5.—A dark bluish-grey or lead-colored layer; like 1*b*, coarse granular, and dull.

SPECIMEN 6*a*.—The dark grey unweathered portion of a layer which was weathered on one surface to a grey-buff color, showing the minute whorled univalve fossil shells very distinctly.

SPECIMEN 6*b*.—The buff, weathered portion of this layer.

SPECIMEN 7.—A thin layer weathered on the two surfaces; moderately dark grey in the interior; more dense than specimen 1; contains the minute univalve fossils.

8.—A thin crystalline layer; of a light grey color, with not much appearance of fossil remains.

9.—A coarser-grained layer, containing fossil remains; somewhat crystalline, and partly weathered.

These eleven samples were severally treated for the determination of phosphoric acid alone. One gramme of each, dried at 212° F., was digested in nitric acid with a little chlorhydric, and then, after evaporation to dryness, the residue was digested for some hours in nitric acid, diluted and filtered. The phosphoric acid was then determined by a careful use of the molybdic acid process, and the results obtained were as follows, viz:

PERCENTAGE OF PHOSPHORIC ACID IN THESE ELEVEN SAMPLES.

In sample 1*a*	contained	7.931 per cent.	of phosphoric acid.
In sample 1*b*	contained	19.183 per cent.	of phosphoric acid.
In sample 2	contained	17.973 per cent.	of phosphoric acid.
In sample 3	contained	11.501 per cent.	of phosphoric acid.
In sample 4	contained	21.940 per cent.	of phosphoric acid.
In sample 5	contained	18.421 per cent.	of phosphoric acid.
In sample 6*a*	contained	20.021 per cent.	of phosphoric acid.
In sample 6*b*	contained	11.705 per cent.	of phosphoric acid
In sample 7	contained	16.502 per cent.	of phosphoric acid.
In sample 8	contained	5.053 per cent.	of phosphoric acid.
In sample 9	contained	13.624 per cent.	of phosphoric acid.

It will be seen that the *maximum* proportion, that in No. 4, is 21.940 per cent.; the *minimum*, in No. 8, is 5.053 per cent., and the *general average* proportion 15.896 per cent.

The greatly varying proportions of this ingredient, within small limits, point to a very irregular local origin.

Frequently the phosphoric acid of the ancient limestone layers is traceable to the brachiopod and other shells and fossils which they contain. In order to ascertain how much of it in the specimens examined is attributable to this source, the specimens described below were collected and analyzed, viz:

No. 2005—"FOSSIL SHELLS, *mostly Orthis testudinaria, from Lower Silurian limestone layers. Farm of R. Peter, about seven miles north of Lexington, near Elkhorn creek.*"

No. 2006—"FOSSIL BRANCHING CHŒTETES, *from the same locality. Collected by R. Peter.*"

Specimen 2005 yielded only 1.317 per cent. of *phosphoric acid*, and contained 11.04 per cent. of silicious matter.

Specimen 2006 gave only 0.294 per cent. of *phosphoric acid*, and 6.16 per cent. of silicious matters.

Evidently there must have been some other source of the abundant phosphates of these layers than the shells of the mollusca, or the corals. Possibly they may have been accumulated by some process of segregation; possibly they may be due to the fortuitous presence of some of the large animals of the ancient seas, which, subsisting on the more simple forms of organic life, may have left their excretions and exuviæ in these localities.

However this may be, while the examination of these layers of our limestone develops an unexpected richness in phosphates, their too irregular distribution amongst the poorer layers may make their special application to the manufacture of fertilizers too practically expensive or precarious.

FRANKLIN COUNTY.

No. 2007—"POTTER'S CLAY, *from a bed several feet in thickness, in the bottom land, in what is supposed to be an old prehistoric channel of the Kentucky river, half a mile north of Frankfort. Collected by Jno. R. Procter.*"

The specimen is part of an unburnt vessel made of the clay at the pottery. The clay is of a grey-drab or neutral tint; it contains some very small specks of mica and of ferruginous matter. It calcines of a very light brick color. Fuses before the blow-pipe.

COMPOSITION, DRIED AT 212° F.

Silica	69.300
Alumina, with iron and manganese oxides	21.780
Lime carbonate	.158
Magnesia	.331
Phosphoric acid	.060
Potash	2.351
Soda	.585
Water and loss	5.435
Total	100.000

Ten grammes of the clay, dried at the common temperature, washed quickly with water, gave 2.45 grammes of *fine sand*, containing some larger, rounded quartz grains.

This clay, while fitted for the manufacture of ordinary pottery ware, is not sufficiently refractory to be used as a fireclay.

GRANT COUNTY.

In an investigation made by Mr. C. J. Norwood of the character of the subsoils, under-clays, and other earthy material, excavated in making some of the deep cuts on the line of the Cincinnati Southern Railroad in this county, the samples described below were collected by him, and sent to the Chemical Laboratory for analysis.

No. 2008—"MATERIAL, *from just below the top soil, extending in thickness from eighteen inches to two feet, down to the surface of the material claimed to be "Hard Pan," next below described, at section* 29, *in the cut at station* 295 *on the C. S. R. R.*"

Quite a tough clayey material, generally of a light grey-buff color when dry, mottled with light grey, and penetrated in all directions with what appear to have been vegetable rootlets, now mainly decomposed, and of a deep manganese oxide color.

No. 2009—"MATERIAL, *claimed to be 'Hard Pan,' beginning at two feet below the surface and extending to the bed-rock.*"

Rather more tough than the preceding, which it resembles in color, except that it has more of the light grey mottling and less of the manganese-like infiltrations. The bolting-cloth separated, from the silicious residue of these two under-clays, only a very few quartz grains.

No. 2010—"TOP SOIL, *from an old field owned by the heirs of Richard Dickerson. Section* 30, *cut at station* 337 *on the C. S. R. R.*"

Dried soil of a light grey-brown color; friable.

No. 2011—"SOIL, *from just below the top soil, from the same locality as the next preceding,*" *&c., &c.*

This dried subsoil, of a firmer, more clayey consistence than the preceding, is of a nearly uniform grey-buff color, mottled somewhat with light bluish-grey, and with some manganese oxide-like infiltrations.

No. 2012—"SUBSOIL, *from the same locality as the two preceding, from just below the next preceding, to the depth of two feet.*"

A clayey subsoil, grey-buff, mottled with light bluish-grey, with some dark-colored manganese oxide infiltrations. Very much like 2008 and 2009, but not so tough as these.

No. 2013—"SUBSOIL OR UNDER-CLAY, *seven inches thick, from the same locality, and immediately below the next preceding*," *&c.*

Resembles the next preceding, but shows more manganese infiltrations, with some small spheroidal concretions of the same, forming blackish spots.

No. 2014—"SUBSOIL OR UNDER-CLAY, *from the same locality, one foot thick, lying immediately below the next preceding.*"

This is a very tough clay-like material, darker in color than the next preceding; of an ochreous greyish-brown tint, with some little mottlings of bluish-grey, and some manganese-like infiltrations.

No. 2015—"SUBSOIL OR UNDER-CLAY, *from the same locality, one foot thick, lying just below the next preceding, and immediately above the bed-rock.*"

This is also quite a tough material, showing more mottling with bluish-grey clay than the preceding, and some manganese infiltrations, and containing some small calcareous nodules.

The bolting-cloth separated from the silicious residues of all these six subsoils or under-clays a considerable proportion of dull, angular fragments of what appeared to be hard silicates, which had not been decomposed by the acids in which they had been digested in the process of analysis.

COMPOSITION OF THESE EIGHT GRANT COUNTY SOILS, SUBSOILS, &c., DRIED AT 212° F.

	No. 2008	No. 2009	No. 2010.	No 2011	No. 2012.	No. 2013.	No. 2014	No. 2015.
Alumina and iron and manganese oxides	13.849	12.675	6.847	9.199	11.672	12.564	15.237	24.465
Lime carbonate	1.420	1.465	.200	.190	.165	.225	2.290	9.425
Magnesia	.513	.600	.420	.420	.398	.609	.383	.286
Phosphoric acid	.636	.435	.188	.086	.188	.236	.823	.589
Potash	.952	.780	.568	.156	.579	.259	1.124	.669
Soda	.082	.617	.317	.368	.104	.246	.019	.245
Water and organic matters lost on ignition	5.515	5.400	5.425	4.100	4.450	5.600	4.950	4.425
Sand and insoluble silicates	77.640	78.965	86.165	85.460	82.490	80.115	75.240	59.940
Total	100.607	100.937	100.130	99.979	100.046	99.854	100.066	100.044
Hygroscopic moisture	5.710	5.950	2.750	3.400	3.825	5.950	6.575	5.250
Potash in the insoluble silicates	2.524	2.511	1.687	1.958	1.533	2.004	2.410	2.703
Soda in the insoluble silicates	.499	1.214	.388	.260	.638	.397	.407	.265
Character of the sample	Subsoil.	Under-clay.	Soil.	Subsoil.	Under-clay.	Under-clay.	Under-clay.	Under-clay.

Subsoils 2008 and 2009, from the same locality, resemble each other, nearly, in chemical composition; their great toughness, mainly due, no doubt, to their large proportions of alumina, may be partly owing to their peculiar mode of aggregation. Their composition, with the exception of the absence of any notable quantity of *humus*, is that of our richest soils; but their physical condition is no doubt unfavorable to fertility. These, as well as the six other samples, were doubtless derived mainly from the so-called "mudstone" strata of the Lower Silurian formation. In these latter samples a regular increase, in the proportion of the aluminous materials, may be observed, as the depth from the surface increases, indicating probably the influence of the infiltration of surface waters. In nearly all of these clays there are large proportions of phosphoric acid and potash.

Other similar samples, collected by Mr. Charles J. Norwood, from the deep cuts of this railroad in Grant county, are described below, as follows:

No. 2016—"SUBSOIL, *twenty-one inches thick, just below the top soil, which is one foot thick. In front of Mrs. Mary Renslaer's house. Section 33. Second cut from the north end of the C. S. R. R., Grant county.*"

Dried subsoil in yellowish-brown, somewhat friable clods. Some little mixture of light ash-grey material observable in it.

The bolting-cloth removed, from its silicious residue, a considerable proportion of soft granules of partly decomposed silicates, but no silicious particles.

No. 2017—"UNDER-CLAY, *from the same locality, eighteen inches thick, lying immediately under the preceding subsoil, and extending down to the underlying limestone,*" *&c.*

This resembles the preceding generally, in color, but is much more tough, and has some dark ferruginous or manganese discolorations, and a little more of the light colored material.

The silicious residue also contains a large proportion of soft, partly decomposed silicate granules.

No. 2018—"SURFACE SOIL, *to the depth of fifteen inches. Section 34. Second cut from the south end, C. S. R. R.," &c.*

A friable earth of a light grey-umber color, containing a few dark concretions. The silicious residue all passed through the bolting-cloth, except a few soft granules of partly decomposed silicates.

No. 2019—"SUBSOIL, *from the same locality as the last, nineteen inches thick, next below the surface soil," &c.*

A somewhat friable subsoil, having a more ferruginous tint than the preceding, and showing some dark colored infiltrations. Silicious residue like the preceding.

No. 2020—"UNDER-CLAY, *one foot thick, same locality as the preceding," &c.*

A somewhat tough clay. Mottled, with light grey-ferruginous of various tints, and nearly black infiltrated manganese oxide. Silicious residue like the preceding.

No. 2021—"UNDER-CLAY, *eighteen inches thick, just below the preceding," &c., &c.*

A tough clay; mottled like the preceding.

No. 2022—"UNDER-CLAY, *two feet thick, on the bed rock, same locality as the preceding," &c., &c.*

Mottled like the preceding. Some parts of it compact and laminated. Contains occasional fragments of limestone and sandstone. Silicious residue like the preceding.

COMPOSITION OF THESE SOILS, SUBSOILS, &c., DRIED AT 212° F.

	No. 2016.	No. 2017.	No. 2018	No. 2019	No. 2020.	No. 2021.	No. 2022.
Alumina and iron and manganese oxides	17.502	27.353	9.540	10.222	18.593	15.437	11.792
Lime carbonate	1.115	4.555	.575	.290	.275	1.225	8.240
Magnesia	.151	.266	.312	.266	.402	.679	.824
Phosphoric acid	.473	.457	.345	.313	.393	.473	.793
Potash	.809	1.585	.587	.150	.611	.809	1.778
Soda	.052	.125	.....	.....	.165	.066	.359
Water and organic matters lost on ignition	5.365	4.675	5.675	3.780	6.290	6.085	4.290
Sand and insoluble silicates	75.090	60.967	83.790	84.890	73.575	75.890	71.924
Total	100.557	99.983	100.824	99.911	100.304	100.664	100.000
Hygroscopic moisture	not est.	not est.	not est.	not est.	not est.	not est	not est.
Potash in the insoluble silicates	1.542	1.487	1.679	1.881	1.489	2.428	2.423
Soda in the insoluble silicates	.297	.212	.510	.552	.486	.376	.324
Character of the sample	Subsoil.	Under-clay.	Surface soil.	Subsoil.	Under-clay.	Under-clay.	Under-clay.

These seven soils, subsoils, and under-clays present a general resemblance, in composition as well as in physical character, to the eight described above. The same remark will apply to the six remaining samples described below, from section No. 35, on the same railroad.

No. 2023—"TOP SOIL *to about one foot in depth, from the cut at the north end in section 35, on the Cincinnati Southern Railroad, Grant county. Collected by C. J. Norwood."*

The dried soil is in friable clods of a dirty drab color, mottled with yellowish and ferruginous. The silicious residue, left after digestion of the soil in acids, all passed through the bolting-cloth, except many soft, whitish, rounded grains of partly decomposed silicates.

No. 2024—"SUBSOIL, *twenty-one inches thick, immediately below the top soil, from the same locality," &c.*

Dried subsoil in friable lumps; mottled with light grey and ferruginous of different tints. Silicious residue like that of the preceding.

No. 2025—"UNDER-CLAY, *two feet thick, lying just under the preceding. Same locality," &c., &c.*

A tough clay, mostly of an ochreous yellow color, mottled with grey-ferruginous, with some nearly black infiltrations of manganese oxide.

No. 2026—"UNDER-CLAY, *eight inches thick, just under the next preceding. Same locality," &c., &c.*

Dried clay not quite so tough as the next preceding; of rather a lighter yellowish color; mottled like that, but with less of the dark colored material. Silicious residue like that of the preceding.

No. 2027—"UNDER-CLAY, *six inches thick, just below the next preceding. Same locality," &c., &c.*

Dried clay in rather friable lumps, generally of a light yellowish brown color, mottled with light ochreous yellow. Silicious residue resembling that of the preceding.

No. 2028—"UNDER-CLAY, *twenty-six inches thick, just under the next preceding, lying on the limestone bed rock, and in some places seeming to replace the bed rock. Same locality as the preceding,"* &c., &c.

Dried clay in rather tough clods, of a brownish yellow color, much mottled with dark brownish ferruginous. Silicious residue like that of the preceding.

COMPOSITION OF THESE SIX GRANT COUNTY SOILS, SUBSOILS, AND UNDER-CLAYS, DRIED AT 212° F.

	No. 2023.	No. 2024.	No. 2025.	No. 2026.	No. 2027.	No. 2028.
Alumina and iron and manganese oxides	7.225	9.852	16.827	14.492	21.124	23.100
Lime carbonate	.470	.390	1.640	2.315	4.305	3.640
Magnesia	.303	.447	.645	.609	.420	.223
Phosphoric acid	.185	.358	.358	.358	.361	.505
Potash	.738	.282	.213	.760	.210	.534
Soda	.....	.....	.337	.....	.308	.....
Water and organic matters lost on ignition	4.650	3.940	5.400	4.450	5.025	5.850
Sand and insoluble silicates	87.065	84.760	75.040	77.440	68.515	66.390
Total	100.636	100.029	100.460	100.424	100.268	100.242
Hygroscopic moisture	not est.	not est.	not est.	not est.	not est.	not est.
Potash in the insoluble silicates	1.812	1.673	2.103	2.851	2.700	2.865
Soda in the insoluble silicates	.722	.677	.433	.417	.378	.449
Character of the sample	Top soil.	Subsoil.	Under-clay.	Under-clay.	Under-clay.	Under-clay.

The general remarks on the first and second groups of these samples will apply equally well to these.

GRAYSON COUNTY.

No. 2029—"VIRGIN SOIL, *to the depth of about eight inches; from Grayson Springs, about four hundred yards west of the railroad. On the Leitchfield marl. Chester Group. Native forest growth, mostly white oak. Yield: of corn,* 25 *to* 40 *bushels; of wheat,* 12 *to* 15 *bushels; of tobacco,* 800 *to* 1,000 *pounds per acre. Good for clover and grasses. Collected by John H. Talbutt."*

Dried soil, somewhat cloddy, of a light buff-grey color. The silicious residue all passed through the bolting-cloth.

No. 2030—"SUBSOIL *of the preceding, taken to the depth of three feet. Collected by John H. Talbutt."*

The dried subsoil is of a dirty orange-grey color. The silicious residue, after digestion in acids, all passed through the bolting-cloth.

COMPOSITION OF THESE SOILS, DRIED AT 212° F.

	No. 2029.	No. 2030.
Organic and volatile matters	3.239	2.534
Alumina and iron and manganese oxides	3.096	4.781
Lime carbonate	.020	.045
Magnesia	.097	.061
Phosphoric acid	.144	.159
Sulphuric acid	not est.	not est.
Potash	.160	.100
Soda	.268	.102
Water, expelled at 380° F.	.506	.483
Sand and insoluble silicates	91.865	91.490
Total	99.395	99.775
Hygroscopic moisture	1.200	1.575
Potash in the insoluble silicates	0.927	1.198
Soda in the insoluble silicates	.262	.254
Character of the soil	Virgin soil.	Subsoil.

These soils, of average natural fertility, would require the application of lime or marl, with phosphatic and alkaline fertilizers, to enable them to maintain, indefinitely, a high degree of productiveness. Judicious rotation of crops, including the sufficient use of ameliorating clover or grass crops, to be grazed or plowed in, together with barn-yard manure, might keep them in good condition for quite a long period, without the application of any outside fertilizers, especially if the products were consumed upon the farm; but when these are exported a gradual deterioration must result in all soils, unless the essential mineral ingredients carried off in the products are in some manner restored.

GREENUP COUNTY.

COALS.

No. 2031—"COAL, *from Cane Creek Mines. New opening in the No. 3 Coal, near Hunnewell Furnace. Average sample No. 1; sent by Mr. H. W. Bates, Vice President of the Eastern Kentucky Railway Company.*"

A fine-looking coal, pitch black, breaking into thin laminæ, with no apparent pyrites, and some fibrous coal.

No. 2032—"COAL. *Average sample No. 2; taken from about one hundred yards from the place of the preceding sample. Same locality,*" *&c., &c.*

Coal not quite so bright as the preceding sample. Some granular pyrites apparent between the laminæ.

No. 2033—"COAL. *Average sample No. 3; from the same locality as the two preceding; taken about one hundred yards distant from the others.*"

Resembles the last sample, but has no apparent granular pyrites. Some fibrous coal between the laminæ.

COMPOSITION OF THESE GREENUP COUNTY COALS, AIR-DRIED.

	No. 2031.	No. 2032.	No. 2033.
Specific gravity	1.345	1.344	1.383
Hygroscopic moisture	6.33	5.77	6.03
Volatile combustible matters	32.42	33.28	30.77
Coke	61.25	60.95	63.20
Total	100.00	100.00	100.00
Total volatile matters	38.75	39.05	36.80
Carbon in the coke	53.30	52.40	50.65
Ash	7.95	8.55	12.55
Total	100.00	100.00	100.00
Character of the coke	Dense spongy.	Dense spongy.	Dense spongy.
Color of the ash	Light lilac-grey.	Light lilac-grey.	Light lilac-grey.
Percentage of sulphur	1.277	0.900	1.458

Considerable local differences may be observed, in the relative proportions of ash and sulphur, in these samples from the same coal bed. They are all good coals of the variety "splint," or "semi-cannel," to which the celebrated "block coal" of Indiana belongs.

HARDIN COUNTY.

SOILS.

No. 2034—"VIRGIN SOIL, *from the farm of Gov. Jno. L. Helm, one mile north of Elizabethtown, Hardin county. Forest growth: beech, hickory, and oaks. Geological formation: St. Louis limestone. Collected by the Rev. H. Hertzer.*"

The dried soil is of a light yellowish-grey umber or dark drab color. The clods are friable. The coarse sieve removed from it a small quantity of ferruginous gravel. The silicious residue, after digestion in acids, all passed through the bolting-cloth, except a small quantity of fine quartz sand and a few particles of partly decomposed silicates.

No. 2035—"SURFACE SOIL, *which has been in cultivation for sixty years. From the same locality as the preceding soil. Average crops: 35 to 45 bushels of corn; 12 bushels of wheat, &c. This farm is considered a poor and worn out one. Decayed rock six to eight feet. Collected by Rev. H. Hertzer.*"

The dried soil is of a dirty-buff color; the clods quite firm. The coarse sieve separated from it a small quantity of ferruginous gravel. The silicious residue left on the bolting-cloth some fine quartz sand of various colors, and some grains of partly decomposed silicates.

No. 2036—"SUBSOIL *of the two preceding soils,*" *&c., &c.*

This dried subsoil is of a handsome deep orange buff color. Its clods are quite firm. The coarse sieve removed from it about five per cent. of rounded ferruginous gravel. The silicious residue resembled that of the two preceding samples.

COMPOSITION OF THESE THREE HARDIN COUNTY SOILS, DRIED AT 212° F.

	No. 2034.	No. 2035.	No. 2036.
Organic and volatile matters	4.495	2.575	2.350
Alumina and iron and manganese oxides	5.579	6.520	9.807
Lime carbonate	.340	.215	.140
Magnesia	.286	.227	.223
Phosphoric acid	.071	.070	.083
Sulphuric acid	not est.	not est.	not est.
Potash	.149	.119	.270
Soda	.037	. . . . .	. . . . .
Water, expelled at 380° F.	1.675	.950	.925
Sand and insoluble silicates	87.675	89.140	85.590
Total	100.307	99.816	99.388
Hygroscopic moisture	1.900	1.510	2.050
Potash in the insoluble silicates	1.250	1.037	0.848
Soda in the insoluble silicates	.432	.376	.286
Character of the soil	Virgin soil.	Old field soil.	Subsoil.

The greatest apparent deficiency in these soils is of the phosphoric acid; this is apparent even in the so-called virgin soil. There can be little doubt that the use of top-dressings of bone-dust, superphosphate, or guano would greatly increase their fertility. Although the old field soil shows evidence of the diminution of its essential mineral ingredients, as well as of its organic and volatile matters, *humus*, it is by no means to be considered "worn out." Judicious culture to restore its *humus*, by means of clover or other green crops, grazed and plowed in, with the use of phosphatic fertilizers, &c., would soon restore its fertility, if the land is properly drained.

No. 2037—"VIRGIN SOIL, *from the farm of J. W. Fowler, Colesburg, Hardin county. Forest growth: poplar, beech, sugar-tree, white and black oaks, hickory, &c. Geological formation: St. Louis Group. Blue calcareo-argillaceous shales. Decomposed rock three to four feet. Collected by the Rev. H. Hertzer.*"

This dried soil is of an umber-grey color. The coarse

sieve separated from it 4.31 per cent. of rounded fragments of silicio-ferruginous concretions or sandstone, with a little chert. The bolting-cloth removed from the silicious residue, after the usual digestion in acids, some small particles of partly decomposed silicates, and a portion of a very small encrinital stem.

No. 2038—"SURFACE SOIL, *thirty-four years in cultivation. From the same farm as the preceding soil, &c., &c. Average crops: of corn, 35 bushels; wheat, 16 bushels; oats, 15 to 20 bushels; of hay, one and a half tons per acre. Collected by Rev. H. Hertzer.*"

Dried soil of a lighter and more yellowish-grey color than the preceding. The coarse sieve removed from it nearly seven per cent. of rounded ferruginous sandstone gravel or concretions, with some cherty fragments. The silicious residue resembled that of the preceding soil.

No. 2039—"SUBSOIL *of the next preceding,*" *&c., &c.*

The dried subsoil resembles the next preceding soil in color. The coarse sieve separated from it nearly nine per cent. of angular cherty fragments, with some silicified portions of encrinital stems and ferruginous gravel. The bolting-cloth removed from the silicious residue a few particles of partly decomposed silicates, one or two small clear quartz grains, and two fragments of minute silicified encrinital stems.

No. 2040—"VIRGIN SOIL, *from the farm of Van Buren Vandecraft, on Muldraugh's Hill, at Colesburg, Hardin county. Forest growth: poplar, beech, white oak, chestnut oak, sugar-tree. Geological formation: St. Louis Group. Decayed rock one to two feet. Collected by Rev. H. Hertzer.*"

Dried soil of a light buff-grey color. The coarse sieve removed from it 10.55 per cent. of angular cherty fragments, with some silicified encrinital stems and iron gravel. The bolting-cloth separated from the silicious residue a considerable proportion of partly decomposed silicate grains, some resembling reddish felspar, with some minute silicified entrochi, and a few quartz grains.

No. 2041—"SURFACE SOIL, *fifty years in cultivation. From the same farm as the preceding soil. Average crop of corn, twenty bushels. Collected by Rev. H. Hertzer.*"

This dried soil is of a brownish salmon color. The coarse sieve separated from it only a small proportion of iron gravel, and a small rounded quartz pebble. The silicious residue resembled that of the preceding soil.

No. 2042—"SUBSOIL *of the next preceding soil,*" *&c., &c.*

The dried subsoil is of a handsome light brick red color. It all passed through the coarse sieve. The bolting-cloth removed from the silicious residue a considerable quantity of partly decomposed silicate grains, which were easily crushed under the finger, together with some blackish silicified portions of encrinital stems, &c.

COMPOSITION OF THESE SIX HARDIN COUNTY SOILS, DRIED AT 212° F.

	No 2037.	No. 2038.	No. 2039.	No. 2040	No. 2041	No. 2042.
Organic and volatile matters	9.185	5.400	4.500	4.610	3.085	3.550
Alumina and iron and manganese oxides	8.705	8.228	8.347	6.033	6.597	11.254
Lime carbonate	1.350	.625	.465	.390	.290	.215
Magnesia	.124	.107	.142	.070	.040	.025
Phosphoric acid	.203	.172	.123	.102	.038	.061
Sulphuric acid	not est.	not est.	not est.	not est.	not est.	not est.
Potash	.595	.279	.175	.316	.035	.251
Soda	.011	.018	.077	.098	.025	.168
Water, expelled at 380° F.	2.715	2.075	2.000	1.625	1.150	1.550
Sand and insoluble silicates	77.905	83 090	84.440	86.355	88.940	83.490
Total	100.793	99.994	100.269	99.599	100.200	100.564
Hygroscopic moisture	2.885	2.315	2.265	1.815	1.335	2.575
Potash in the insoluble silicates	2.910	2.226	1.137	0.956	1.302	1.329
Soda in the insoluble silicates	1.166	.786	.733	.197	.443	.256
Character of the soil	Virgin soil	Old field soil.	Subsoil.	Virgin soil	Old field soil.	Subsoil.

It is interesting to notice in these soils the changes in composition brought about by long cultivation without the use of fertilizers. In the case of soils Nos. 2037 and 2038 the organic and volatile matters have been reduced from 9.185 to 5.400 per cent. by the thirty-four years of cultivation; the

lime carbonate from 1.350 to 0.625; the phosphoric acid from 0.203 to 0.172, and the potash from 0.595 to 0.279 per cent., while the percentage of sand and insoluble silicates is increased from 77.915 to 83.090 per cent. In the soils Nos. 2040 and 2041 we find that the sixty years' cropping of the latter have reduced some of its essential ingredients in still greater proportion. The organic matters, &c., are reduced from 4.610 per cent. to 3.085; the lime carbonate from 0.390 to 0.290; the phosphoric acid from 0.102 to 0.038 per cent., the potash from 0.316 to 0.035 per cent., and the sand and insoluble silicates are increased from 86.355 to 88.940 per cent.

The first set of soils was evidently naturally the richer; and the relative present productiveness of the soil of the two old fields corresponds nearly with their comparative richness or poverty, as shown by their chemical composition; for while the soil No. 2038 produces thirty-five bushels of corn per acre, soil No. 2041 yields only twenty bushels. This latter soil is greatly in want of phosphatic fertilizers, as well as those containing potash salts. There is no apparent reason why, by the proper use of such fertilizers, barn-yard manure, and a judicious system of rotation, with the cultivation of ameliorating green crops for grazing purposes and for plowing under, these soils may not be brought to and maintained in a condition of profitable productiveness.

HARRISON COUNTY.

No. 2043—*Some* LEAD ORE (*galena*), *mixed with zinc blende; in a gangue of barium sulphate, which included some angular fragments of embedded limestone; was brought to the laboratory by Mr. John R. Procter for analysis.*

This ore, reported to be argentiferous, is found in a vein of heavy spar, on the farm of the late Mr. Shawhan, one mile on the Lexington side of Cynthiana, on the Kentucky Central Railroad.

The lead sulphide was disseminated, in rather small proportion in the samples brought, throughout the gangue, and when reduced in the usual way, and analyzed, both by the wet way and by cupellation, it was not found to yield more than a trace of silver, in a lead button weighing more than eight grammes, obtained from thirty grammes of the galena: so that it evidently could not be profitably worked for this precious metal. The rather small proportion of lead ore seems also to preclude the profitable operation of this mine for the baser metal.

HOPKINS COUNTY.

SOILS.

No. 2044—"VIRGIN SOIL; *surface soil to the depth of thirteen inches; from woods on the farm of Mr. Mills, near Nortonsville. Collected by John H. Talbutt." Forest growth generally oaks. Slope of the surface west-south. Sample taken near the base of the hill, near a coal-shaft.*

The dried soil is of a dark umber-grey color. The coarse sieve removed from it a few small ferruginous concretions. The bolting-cloth separated from the silicious residue, remaining after the digestion in acids, 16.5 per cent. of the soil of fine white sand, composed of rounded quartz grains.

No. 2045—"SUBSOIL *of the preceding," &c., &c.*

The dried subsoil is in friable clods, of a brownish buff color. It all passed through the coarse sieve. The bolting-cloth removed from the silicious residue 10.50 per cent. of the soil of fine white sand, like that of the preceding.

COMPOSITION OF THESE HOPKINS COUNTY SOILS, DRIED AT 212° F.

	No. 2044.	No. 2045.
Organic and volatile matters	2.850	2.090
Alumina and iron and manganese oxides	4.952	6.883
Lime carbonate	.080	a trace.
Magnesia	.106	.181
Phosphoric acid	.083	.077
Sulphuric acid	not est.	not est.
Potash	.145	.307
Soda	.050	. . . .
Water, expelled at 380° F.	.737	.660
Sand and insoluble silicates	90.540	89.700
Total	99.543	99.898
Hygroscopic moisture	1.085	1.285
Potash in the insoluble silicates	1.693	1.458
Soda in the insoluble silicates	.687	.697
Character of the soil	Virgin soil.	Subsoil.

These must be classed amongst the naturally weak soils, especially because of their small proportion of lime and phosphoric acid. These necessary ingredients can, however, be easily supplied in bone-dust, superphosphate, or guano, which, with a further supply of potash in some appropriate fertilizer, might make this soil quite productive, especially if proper means be used to increase the proportion of *humus*, organic and volatile matters, which are also in too small proportion in this soil.

JACKSON COUNTY.

No. 2046—"BLACK BAND IRON ORE. *On top of the thirty-four inch coal. Coyle's Bank. Big Hill, Jackson county. Collected by John R. Procter."*

A dull, rusty-black ore; ferruginous on the weathered surfaces; shaly in structure. Some small reedy impressions between some of the irregular laminæ. Some granular pyrites apparent also.

COMPOSITION, DRIED AT 212° F.

Iron carbonate	70.168,	containing 33.875 iron.
Alumina and trace of manganese oxide	.430	
Lime carbonate	.930	
Magnesia carbonate	2.898	
Phosphoric acid	.345	= .151 phosphorus.
Sulphur	.264	
Bituminous matters	18.540	
Silicious residue	6.230,	containing 4.960 silica.
Total	99.805	

If this ore is found in sufficient abundance, it may be smelted with advantage, for the production of iron of a low grade for ordinary purposes. Deducting the 18.54 per cent. of bituminous matters, which will act in the smelting furnace like so much fuel, the percentage of iron to the remainder is more than forty-one and a half.

JESSAMINE COUNTY.

No. 2047—"MINERAL WATER. *Salt sulphur water, from a well fifteen feet deep; in the Lower Silurian blue limestone; on the farm of James Llewellyn, on the Russell's Tavern turnpike, about two miles west of Nicholasville. Sample brought by Mr. B. M. Arnott.*" (Analyzed by my son, Alfred Meredith Peter, under my supervision.)

The water, brought to the laboratory in a stone-ware jug, corked and well sealed with wax, smelt strongly of hydrogen sulphide, but was somewhat turbid with a dark grey precipitate of iron sulphide, &c.

SUMMARY OF THE ANALYSIS MADE.

Carbonic acid gas, present but not estimated, because a part had escaped. Hydrogen sulphide gas, the quantity yet remaining was 0.015 gramme per litre, equal to 0.109 grain or 0.3 cubic inch per wine pint. Of course much more is present in the water at the well. The following named carbonates were found in the water, they being held in solution by the carbonic acid present, viz: lime, magnesia, iron and strontia carbonates, making a total weight of 0.276 gramme per litre; equal to 1.592 grains per wine pint of the water. (The litre equals 1000 grammes.) In the water, which had been boiled

and had deposited these carbonates, the following ingredients were found:

	In 1000 parts.	In a wine pint of the water.
Lime sulphate	0.016	0.117 of a grain.
Potash sulphate	not estimated.	
Magnesium chloride	.171	1.244 grain.
Sodium chloride	much; not est.	
Lithium chloride	a marked trace.	
Sodium bromide	considerable.	
Sodium sulphide	.052	.379 of a grain.
Silica	not estimated.	
Organic matters	not estimated.	
Total saline matters	4.882 per litre.	35.585 grains in the wine pint.

This is a very good salt sulphur water, resembling in its general composition the waters of the Blue Lick Springs and of Col. J. W. Hunt Reynolds' well, near Frankfort, as well as that of the salt sulphur well at the Olympian Springs, in Bath county.

The free hydrogen sulphide (sulphuretted hydrogen) and the sodium sulphide are nearly in the same proportions as in the Lower Blue Lick water; but the total saline matters are only about half as much. The difference may be mainly in the sodium chloride or common salt. These total saline matters, about five parts to the 1000 of the water, or about 55.5 grains to the wine pint, are nearly in the same amount as in the salt sulphur water of the Olympian Springs; but this water contains larger proportions of sodium sulphide and iron carbonate than that. It also is evidently somewhat stronger in hydrogen sulphide than the Olympian water.

There can be no doubt that this salt sulphur water may be beneficially employed, under judicious medical advice, in the treatment of many cases of disease for which sulphur waters are appropriate, especially as it is somewhat chalybeate when taken fresh from the well. Like all other sulphur waters, it soon decomposes when exposed freely to the air.

A more complete analysis would be necessary to determine the exact proportions of all its ingredients, requiring a visit to the well, for the testing of the recent water, and the use of a larger quantity of it at the laboratory.

LINCOLN COUNTY.

No. 2048—MINERAL WATER. "*Salt sulphur water, from a spring in the Black Devonian shale, at the Cincinnati Southern Railroad bridge over Green river; at about the level of the river; discovered by excavating for a 'borrow pit.' Sent for examination by R. M. Bishop, Esq. (now Governor of Ohio).*"

Although the water had been brought in a rather loosely stoppered bottle, it yet smelt and tasted strongly of compounds of sulphur. It was slightly turbid from the spontaneous precipitation of sulphur and iron sulphide, and was of a slightly yellowish tint, doubtless from the presence of sulphuretted sulphides, the result of partial decomposition of the hydrogen sulphide. Of course only a qualitative analysis could be made with the small amount of water supplied, under the circumstances.

SUMMARY.

The water was found to contain carbonic acid and hydrogen sulphide gases in considerable proportion. Held in solution by the carbonic acid were carbonates of lime, magnesia, and iron, and probably of strontia. It contains a large proportion of sodium chloride (common salt), with magnesium chloride and a trace of lithium chloride, besides a notable quantity of lime, magnesia, and potash sulphates, and sodium sulphide. It resembles, therefore, the Blue Lick water, but is much stronger in total saline matters and probably in sodium sulphide. The total saline matters of the Lower Blue Lick water amount to somewhat more than ten parts in the thousand, while those of this water equal about nineteen to the thousand of the water.

If this spring proves to be a constant one, the water deserves a complete quantitative analysis, and it could no doubt be made available as a remedial agent in many cases of disease.

LOGAN COUNTY.

SOILS.

No. 2049—"VIRGIN SOIL, *from the bottom land of Wm. Morton, one mile north of Russellville, Logan county. Collected by Rev. H. Hertzer. Geological formation, St. Louis limestone. Forest growth: a natural canebrake, sycamore, elm, wild cherry, burr oak,*" *&c.*

The dried soil is mostly in friable clods, of a yellowish, light umber color. It contains no gravel. The silicious residue, left after digestion in acids, all passed through bolting-cloth, except a few particles of partly decomposed silicates and a small quantity of small rounded quartz grains, mostly colorless.

No. 2050—"SUBSOIL *to the bottom land above described,*" *&c.*

The dried subsoil is in clods, less friable than those of the above surface soil; of a light yellowish-brick color. It contains no gravel. The bolting-cloth separated from the silicious residue a considerable quantity of small rounded grains of milky and transparent quartz, also much of partly decomposed silicates in small, rounded, soft particles.

No. 2051—"SURFACE SOIL, *in cultivation thirty years; bottom land; from same farm as the two preceding. Average crops: of corn,* 30 *bushels; wheat,* 10 *bushels; oats,* 10 *to* 15 *bushels per acre. Collected by Rev. H. Hertzer.*"

Dried soil in pretty firm clods; of a dark umber-buff color, or light buff-umber. Clods mottled with light brick color. The coarse sieve removed from it a very few small ferruginous quartzy particles. The silicious residue contained rather more small quartz grains, and soft partly decomposed silicate particles, than the preceding.

No. 2052—"Black Soil" (so-called); "*non-productive; all vegetables raised on it look sickly. Surface soil, from the Edgetown stock farm of H. B. Tully, Russellville. Collected by Rev. H. Hertzer.*"

The dried soil is in pretty firm clods, of a dark snuff-brown color. It contains no gravel. The silicious residue all passed through bolting-cloth, except a few small quartz grains, and a considerable proportion of soft rounded particles of partly decomposed silicates.

No. 2053—"Subsoil, *taken from a depth of six feet. From the same locality as the next preceding. Collected by Rev. H. Hertzer.*"

"It is the richest virgin soil from the decomposition of the St. Louis limestone, which rests underneath, partly decayed to six feet in depth. This subsoil, mixed with the lighter surface soil, makes very good bricks, and always enriches the surface soil when properly plowed up. It is preferred for the production of fine tobacco, characterized by broad silky leaves and small stems or midribs. Forest growth, cedar and black walnut."

This dried subsoil is of a bright brick-red color. It is somewhat cloddy. The coarse sieve removed from it some few angular particles of partly decomposed chert. The silicious residue all passed through the bolting-cloth, except a few small rounded grains of transparent quartz, and a considerable quantity of soft particles of partly decomposed silicates.

No. 2054—"Surface Soil, *in cultivation for about thirty years. From the same locality as the preceding. Crops, generally of corn, the average yield of which is thirty bushels. Original growth: black walnut, elm, wild cherry, red and post oaks. Collected by Rev. H. Hertzer.*"

The dried soil is in friable clods of a light buff-umber color. Contains no gravel. Silicious residue like that of the next preceding.

No. 2055—"Subsoil *of the next preceding," &c., &c.*

Dried subsoil of a light brick color, in pretty firm clods. The coarse sieve separated from it a few particles of decomposing chert. The silicious residue is like that of the preceding.

COMPOSITION OF THESE LOGAN COUNTY SOILS, DRIED AT 212° F.

	No. 2049.	No. 2050.	No. 2051.	No. 2052	No. 2053	No. 2054.	No. 2055.
Organic and volatile matters	2.900	2.585	2.560	3.925	3.675	2.775	3.048
Alumina and iron and manganese oxides	3.247	7.095	5.297	8.315	11.811	4.812	9.158
Lime carbonate	.395	.210	.195	.640	.245	.180	.180
Magnesia	.115	.196	.160	.346	.227	.170	.214
Phosphoric acid	.093	.115	.093	.125	.109	.093	.077
Sulphuric acid	not est.	not est.	not est.	not est.	not est.	not est.	not est.
Potash	.132	.169	.121	.060	.212	.085	.326
Soda	.....	.....	.068	.....	.015	.....	.050
Water, expelled at 380° F.	.875	.765	.765	1.275	.950	.600	.775
Sand and insoluble silicates	92.350	88.755	90.935	85.035	82.365	91.090	86.275
Total	100.107	99.890	100.194	99.721	99.609	99.805	100.103
Hygroscopic moisture	1.435	2.385	1.550	2.675	3.800	1.250	2.525
Potash in the insoluble silicates	0.890	1.334	1.286	1.212	1.349	1.474	1.320
Soda in the insoluble silicates	.301	.357	.299	.353	.266	.532	.265
Character of the soil	Virgin soil	Subsoil.	Old field soil.	Black soil	Subsoil.	Old field soil.	Subsoil.

The group of soils Nos. 2049, 2050, and 2051 are naturally of average fertility, if they are sufficiently underdrained, with the exception that the virgin surface soil appears to be rather deficient in phosphoric acid and organic matters or *humus*. The use of phosphatic fertilizers, and the cultivation of green crops—of clover or grasses—to be grazed or plowed under, or of barn-yard manure, would no doubt greatly increase their productiveness. The surface could also be improved by a gradual mixture of the heavier subsoil with the surface soil during this process of amelioration.

The unproductiveness of the black soil seems to be partly due to a deficiency of potash. Possibly, however, the land is not sufficiently underdrained. If there is no want of drainage, the application of wood ashes, or other fertilizers containing potash, would undoubtedly restore productiveness, especially, as in other respects, this soil is not deficient in the essential elements. The red subsoil of the same locality, No.

2052, would no doubt answer the same purpose, because of its considerable proportion of potash, which may account for its favorable influence on the tobacco plant. Subsoils, however, should generally be *gradually* mixed with the surface soil, and accompanied by barn-yard manure, or some other organic fertilizer, to supply *humus*.

The influence of the thirty years' cultivation on the soil of the old fields is manifest in the reduction of the proportions of potash, phosphoric acid, lime, &c., and the increased proportion of the silicious material, as compared with the original soil. The continued cultivation of hoed or plowed crops, such as corn, for a long series of years, has a very deteriorating effect upon the soil, not only because the single crop generally draws inordinately on one kind of mineral matter, as, for example, the corn makes a great demand on the phosphoric acid of the soil, but also because the constantly exposed surface is greatly subject to the washing action of the atmospheric waters, which continually carry off its lighter and richer ingredients, while its *humus* is more than usually removed by the oxydating action of the air. A judicious rotation, in which green crops, covering the soil for a time, undisturbed by the plow, may protect the land from this washing and decomposing influence of the atmospheric agencies, while they, when grazed or plowed under, in whole or in part, may renew the *humus*, and bring the mineral ingredients of the soil into a soluble and available condition for the nourishment of intermediate grain crops, or even of tobacco crops, would conduce greatly to profitable farming, more especially if manures or fertilizers are applied to the green crops. The tobacco plant, which makes so heavy a demand on the soil for potash and lime, as well as phosphoric acid, undoubtedly requires a system of this kind for its continued or profitable cultivation.

LYON COUNTY.

Iron Ores.

No. 2056—"Limonite. *Labeled iron ore, from Hall's patch drift, Lyon county. Centre Furnace. Collected by P. N. Moore.*"

Mostly in dense, hard, brown, irregular laminæ, but containing a considerable proportion of red and yellow porous and soft ochreous material.

No. 2057—"Limonite. *Ore from Skillian Bank. Centre Furnace, Lyon county. Collected by P. N. Moore.*"

Mostly in dense, hard, dark-brown and blackish irregular layers, with but little of softer, reddish, brownish and yellow ochreous material.

Other Centre Furnace iron ores may be found under Trigg county.

COMPOSITION OF THESE LYON COUNTY IRON ORES, DRIED AT 212° F.

	No. 2056.	No. 2057.
Iron peroxide	66.192	68.162
Alumina } Manganese oxide }	1.393	1.763
Lime carbonate	a trace.	a trace.
Magnesia	a trace.	a trace.
Phosphoric acid	.185	.505
Sulphuric acid	a trace.	a trace.
Combined water	10.000	9.630
Silica and insoluble silicates	22.910	20.050
Total	100.680	100.110
Percentage of iron	46.320	47.703
Percentage of phosphorus	.079	.220
Percentage of sulphur	a trace.	a trace.
Percentage of silica	21.820	19.060

These are evidently very good iron ores, more especially No. 2056, which contains much the less of the injurious ingredient, phosphorus, and which, consequently, would yield quite a tough iron by judicious smelting.

MADISON COUNTY.

No. 2058—"COAL, *from Marshall Moran's Bank, Big Hill. Thickness of the bed about thirty-four inches. Average sample by John R. Procter.*"

A sub-conglomerate coal. A firm, pure-looking splint coal. Has some fibrous coal between the thin laminæ, but very little appearance of pyrites.

COMPOSITION, AIR-DRIED.

Hygroscopic moisture	3.57	Total volatile matters	40.10
Volatile combustible matters	36.53		
Light spongy coke	59.90	Carbon in the coke	55.77
		Light yellowish-grey ash	4.13
	100.00		100.00

The percentage of sulphur is only 0.749.

In volume IV of new series of these Reports, pages 109, 110, may be found the analyses of other samples of the coal from this layer, exhibiting considerable differences in the relative proportions of sulphur, &c., &c. No doubt the present sample is a better average sample than No. 1878, which exhibits so much larger quantity of sulphur.

No. 2059—MINERAL WATER. "*Sulphur water; from a well owned by Dr. J. Reed; bored seven hundred and fifty feet deep; begun in the Black Devonian shale, and probably passing into the Trenton limestone, near Paint Lick. Collected by John R. Procter.*"

This water, brought to the laboratory in a corked bottle, had of course lost most of its hydrogen sulphide by decomposition. It yet smelt of this compound, and was of a slightly yellowish tint, from the presence of a little sodium sulphide. It could not be quantitatively analyzed, but the evaporation of a portion of it showed that it contained a quantity of solid saline matters equal to 0.2892 to the 1000 parts, or about two grains to the wine pint. These were found, by testing, to consist of carbonates of lime, magnesia, iron, &c., held in solution by carbonic acid, and sulphates of magnesia, lime, and probably of potash, with small quantities of chloride and sulphide of sodium, &c. No doubt it is a good sulphur water, which deserves a complete analysis.

No. 2060—"RED BUD SOIL, *from the Covington farm, thirty-four miles east of Lexington, half a mile back of Elliston, Madison county. Collected by Mr. L. H. DeFriese.*"

"On the hill slope, nineteen degrees west, below the outcrop of the magnesian limestone and black Devonian shale. Depth of the surface soil, twelve to fifteen inches. Forest growth: red oak, burr oak, honey and black locusts, white and black walnuts, hickories, sycamore, maple, black, blue, and white ash, &c. Yield: thirty to fifty bushels of corn, eight to fifteen of wheat, fifteen to twenty of oats. No hemp raised, and but little rye."

The dried soil is of a brown-umber color. The coarse sieve separated from it 1.14 per cent. of ferruginous and cherty particles. The bolting-cloth removed, from its silicious residue, a considerable portion of fine rounded quartzose grains, mostly transparent, with a few dark colored particles of undecomposed silicates.

COMPOSITION, DRIED AT 212° F.

Organic and volatile matters	5.825
Alumina and iron and manganese oxides	10.434
Lime carbonate	.615
Magnesia	.043
Phosphoric acid	.301
Potash	.379
Soda	.094
Water, expelled at 380° F.	2.415
Sand and insoluble silicates	78.965
Total	99.071
Hygroscopic moisture	3.165
Potash in the insoluble silicates	1.537
Soda in the insoluble silicates	.300

On reference to volume IV, first series of Reports of the Kentucky Geological Survey, page 215, it will be seen that this rich soil has undergone some deterioration since the analyses there reported were made, about eighteen years ago. According to the description of soil No. 1128, given on page 214, it was collected from the same place, or nearly so, as the soil above described. Local differences, however, may exist, making the comparison imperfect.

M'CRACKEN COUNTY.

No. 2061—"SURFACE SOIL, *to the depth of eight inches. From the farm of L. M. Flournoy, three miles from Paducah. Tertiary formation, &c. Forest growth: mostly oaks of various species, with some hickories, &c. The corn crop averages twenty-five to forty bushels per acre. It is good tobacco soil, and considered average soil of the county. Some sandstone in the ravines, and indications of iron ore within half a mile. Collected by John H. Talbutt.*"

The dried soil is of a light greyish-buff color; friable. The coarse sieve removed from it only a few small fragments of decomposing chert. The bolting-cloth separated, from its silicious residue, only a few small particles of partly decomposed silicates.

No. 2062—"SUBSOIL *of the next preceding,*" *&c.*

The dried subsoil is of a darker buff color, and the clods are more adhesive than those of the above; they are mottled with greyish and darker buff. It all passed through the coarse sieve. Silicious residue like that of the preceding.

No. 2063—"UNDER-CLAY *of the two preceding soils, &c. (Sand beneath this),*" *&c.*

The dried under-clay resembles the subsoil, but the clods are more firm. All passed through the coarse sieve. The bolting-cloth removed from the silicious residue a large proportion of particles of partly decomposed silicates.

COMPOSITION OF THESE McCRACKEN COUNTY SOILS, DRIED AT 212° F.

	No. 2061.	No. 2062.	No. 2063
Organic and volatile matters	2.050	2.650	2.675
Alumina and iron and manganese oxides	5.497	12.300	10.834
Lime carbonate	.115	.190	.190
Magnesia	.268	.521	.649
Phosphoric acid	.093	.115	.061
Potash	.167	.284	.643
Soda	.171	. . . .	.087
Water, expelled at 380° F.	1.000	1.000	1.000
Sand and insoluble silicates	90.940	82.490	83.865
Total	100.301	99.550	100.004
Hygroscopic moisture	1.425	4.000	3.425
Potash in the insoluble silicates	1.700	1.605	1.427
Soda in the insoluble silicates	.598	.911	.668
Character of the soil	Surface soil	Subsoil.	Under-clay

These soils, of average natural fertility, could no doubt be greatly improved in productiveness by the use of top-dressings of phosphatic fertilizers, such as bone-dust, superphosphate, or guano. The subsoil is richer than the surface, especially in potash, and might be gradually plowed up and mixed with it in cultivation with advantage. The manurial products of the barn-yard and stables, both solid and liquid, should be carefully husbanded and regularly used upon the soil. There is no reason why a very high degree of productiveness may not be maintained on this soil by a judicious system of farming, in the proper use of fertilizers, and a due rotation of crops, if it is well drained.

MEADE COUNTY.

SOILS.

No. 2064—"VIRGIN SURFACE SOIL, *from the land of Mr. McCarty, Muldraugh, Meade county. Sample taken twenty yards from the railroad, half a mile from the station. Underlying rock, buff and blue sandstone of the Waverly Group. Collected by John H. Talbutt.*"

"Forest growth, white oaks, some trees five feet in diameter; poplar (liriodendron), some eight feet in diameter; large chestnut, beech, red oak, shellbark hickory, some sugar-tree, &c. Average corn crop, twenty to thirty bushels."

Dried soil of a brownish umber-grey color. Clods somewhat adhesive. It all passed through the coarse sieve, except some small angular fragments of weathered chert, and a little shot iron ore. The bolting-cloth removed, from the silicious residue, some rounded grains of quartz and of dark colored silicates.

No. 2065—"SUBSOIL *to the preceding,*" *&c., &c.*

The dried subsoil is cloddy. Its general color is reddish ferruginous, mottled with lighter colored and grey. It contains fragments of weathered chert. The clods are quite firm. The silicious residue contains a small quantity of small rounded quartz grains.

No. 2066—"UNDER-CLAY *below the two preceding,*" *&c., &c.*

Clods quite adhesive. Generally of a handsome buff color, mottled and infiltrated with red ferruginous. It contains a considerable proportion of fragments of weathered chert.

COMPOSITION OF THESE MEADE COUNTY SOILS, DRIED AT 212° F.

	No. 2064.	No. 2065.	No. 2066.
Organic and volatile matters	3.565	5.665	3.600
Alumina and iron and manganese oxides	5.091	15.741	11.604
Lime carbonate	.095	.070	.045
Magnesia	.133	.242	.538
Phosphoric acid	.109	.140	.156
Potash	.156	.425	1.082
Soda	.....	.....	.....
Water, expelled at 380° F.	1.000	1.335	.650
Sand and insoluble silicates	89.725	75.825	82.125
Total	99.874	99.443	99.800
Hygroscopic moisture	1.600	4.265	2.950
Potash in the insoluble silicates	1.297	1.540	2.259
Soda in the insoluble silicates	.471	.304	.150
Character of the soil	Virgin surface soil.	Subsoil.	Under-clay

These soils would be greatly improved by top-dressings of lime or calcareous marl in considerable quantity. The subsoil and under-clay are quite rich in potash, and might be gradually mixed with the upper soil during cultivation. The small average crop of corn is probably due, in part, to the paucity of lime in these soils.

MERCER COUNTY.

No. 2067—"LIMESTONE, *containing green sand or glauconite. Sent by Mr. H. L. Tabler, of Harrodsburg, who says there is a bed of it two feet thick near that place.*"

A dull, grey, fine-granular limestone, containing a large proportion of small, rounded, bluish-green grains of what seems to be green sand or glauconite, together with a considerable proportion of bright, minute, cubical iron pyrites.

Some of the limestone, coarsely powdered, was digested in a warm solution of ammonium nitrate, afterwards in weak chlorhydric acid, to remove the calcium carbonate. The residue was then ignited to remove sulphur from the iron bi-sulphide, after which the iron proto-sulphide was separated by means of a magnet.

The remaining green particles were fused with mixed alkalies, and analyzed, with the following result, viz:

Silica	58.120
Iron and manganese oxides and alumina	32.398
Lime	.784
Magnesia	.807
Phosphoric acid	.102
Alkalies and loss	7.789
Total	100.000

The proportion of the green particles in the limestone was not ascertained, but the whole material fused readily before the blow-pipe, with intumescence, into a dark colored slag. Some of the original limestone was also examined as to its alkaline ingredients, and was found to yield: of potash, 3.372

per cent.; of soda, .319 per cent.; so that there is little doubt that the green particles are glauconite.

As to the probable economic uses of this green limestone layer, little can be said. Some of it was calcined, in a powdered state, and tested as to its availability in the manufacture of hydraulic cement, but it was found not to harden in water. Possibly calcination with more lime might develop this property. It is possible, also, that careful calcination alone, or with more lime, might make it available as an alkaline fertilizer.

NICHOLAS COUNTY.

No. 2068—"MINERAL WATER. *Re-examination of the salt sulphur water of the celebrated Lower Blue Lick Spring.*"

About twenty-seven years have passed since the present writer submitted this water to a quantitative chemical analysis, the results of which, published at the time, are reproduced in volume III of the first series of Reports of the Geological Survey of Kentucky (see pages 361 to 368). Desiring to ascertain whether any material change had occurred during this lapse of time, in the general composition of this water, and also to search for and determine some of its minuter ingredients, not at that time sought for, a new examination was made of it; Messrs. Hamilton, Gray & Co., of Maysville, having kindly placed at the disposal of the writer a barrel of the recent water.

The comparative results of the two analyses, made twenty-seven years apart, show a remarkable resemblance, proving that this celebrated water has not been sensibly weakened or altered in composition during this period, as follows:

COMPOSITION IN 1000 MEASURED PARTS OF THE WATER.

	Analysis 1850.	Analysis 1877.
Specific gravity	1.007	1.0072
Sulphuretted hydrogen gas	0.3947	not determ'd.
Free carbonic acid gas	.3547	not determ'd.
Lime carbonate	0.3850	0.3184
Magnesia carbonate	.0022	.0211
Alumina, phosphate of lime and iron carbonate	.0058	.0038
Sodium chloride	8.3473	8.3571
Potassium chloride	.0227	.1860
Magnesium chloride	.5272	.4864
Magnesium bromide	.0039	.0195
Magnesium iodide	.0007	.0003
Lime sulphate	.5533	.5508
Potash sulphate	.1519	....
Calcium chloride	....	.0606
Lithium chloride	....	.0060
Sodium sulphide	....	.0307
Soda carbonate	....	.0140
Soda bi-borate	....	.0298
Baryta sulphate	....	.0002
Strontia sulphate	....	.0011
Silicic acid	.0179	.0149
Organic acids and loss	.2821	.4573
Total saline matters in 1000 parts	10.3000	10.5580

The minuter ingredients discovered in this water, in this more complete analysis, are compounds of lithium, barium, strontium, and boron, as well as small quantities of sodium sulphide and soda carbonate.

The two latter compounds, with the soda bi-borate, give a slightly alkaline reaction to the water, and the sodium sulphide gives it greater durability as a *sulphur* water than the hydrogen sulphide alone does. The notable proportion of soda bi-borate doubtless adds to its medicinal virtues. As for the compounds of barium and strontium, they are in so small proportions, and probably in the nearly inert form of sulphates, that it is doubtful whether any influence can be attributed to them. It has not been fully determined whether the compounds of lithium, in such small quantities as they are usually found in mineral waters, exert any curative influence whatever; but doubtless these, as well as the other minute ingredients, are not without effect in this complex solution. Practical experience alone in the use of such waters must determine these questions.

OHIO COUNTY.

IRON ORES.

No. 2069—"CLAY IRONSTONE, *from Wm. Downs' 'Iron Mountain.' Rough creek, above Hartford, near the base of the coal measures. Second bed, three to six inches thick. Collected by C. J. Norwood.*"

A compact, fine granular, dark-grey ore. Not adhering to the tongue. Exterior thinly incrusted with limonite.

No. 2070—"CLAY IRONSTONE. *From the same locality. Third ore bed. Composed of two layers, with a thin clay parting, measuring from three to four and two to four inches, severally. Collected by C. J. Norwood.*"

Resembles the preceding.

No. 2071—"CLAY IRONSTONE. *From the same locality. Fourth ore bed. Six inches thick. Collected by C. J. Norwood.*"

Resembles the preceding, but has more exterior limonite.

COMPOSITION OF THESE CLAY IRONSTONES, DRIED AT 212° F.

	No. 2069.	No. 2070.	No. 2071.
Iron carbonate	60.012	69.117	48.211
Iron peroxide	not est.	not est.	9.227
Alumina and manganese oxide	11.451	7.437	7.307
Lime carbonate	4.430	4.780	5.880
Magnesia carbonate	5.395	4.639	4.298
Phosphoric acid	.377	.786	1.805
Sulphuric acid	trace.	.084	.030
Silica and insoluble silicates	17.280	11.480	19.850
Water and organic matters	1.055	1.677	3.392
Total	100.000	100.000	100.000
Percentage of iron	29.557	32.294	29.484
Percentage of phosphorus	.146	.343	.475
Percentage of sulphur	trace.	.034	.012
Percentage of silica	13.860	6.860	17.460

While these claystone ores could not be made to compete with limonite ores of favorable composition in the production of the best tough iron, they may yet be made available, in the

vicinity of abundant cheap fuel and limestone, for the production of cheap iron for many uses. Of course the preliminary of roasting these ores will be necessary.

No. 2072—"LIMESTONE, *under Coal A, Ben's Lick Hill. On the hill above Brown's Coal Bank, three miles southwest from Hartford, Ohio county. Collected by C. J. Norwood.*"

A compact or fine granular fossiliferous limestone, of a dirty grey color, presenting a somewhat brecciated appearance in parts, with ferruginous stains in the veins.

No. 2073—"LIMESTONE, *ferruginous, below Coal D, on Rough creek, mouth of Brush creek, three miles below Hartford. Collected by C. J. Norwood.*" (*Will it serve for cement?*)

A compact or very fine-grained limestone. Interior generally dark slate-grey; exterior, and in the veins, ochreous. Somewhat brecciated in parts.

Some of this rock, in the state of powder, was heated to redness in an open crucible, for an hour and a half, then mixed into a stiff paste with cold water—a portion with sand, and a part without sand; the wet lumps were exposed to a moist atmosphere for a day, and then immersed in water. The lump containing no sand *hardened completely;* that with the sand did not become so hard.

COMPOSITION OF THESE OHIO COUNTY LIMESTONES, DRIED AT 212° F.

	No. 2072.	No. 2073.
Lime carbonate	90.780	41.680
Magnesia carbonate	1.501	22.748
Alumina and iron and manganese oxides	1.189	8.640
Phosphoric acid	.371	.153
Sulphuric acid	not est.	not est.
Potash	.327	1.253
Soda	.100	.323
Silicious residue	4.160	24.060
Moisture and loss	1.572	1.143
Total	100.000	100.000
Percentage of lime	50.837	23.341

While the first sample will yield very good lime for ordinary purposes, the second may make very good hydraulic cement by careful calcination. It does not require as much sand as other hydraulic limestones which contain a smaller proportion of silicious matters.

CLAYS OF OHIO COUNTY.

No. 2074—"INDURATED CLAY, *below Coal F, mouth of Brush Run, on Rough creek. Collected by C. J. Norwood.*"

A dark-grey shaly-clay, with impressions and remains of reed-like leaves, and some ferruginous stains.

No. 2075—"CLAY, *from near Elm Lick, on R. B. Thompson's land. Coal measures. A good deal used in Louisville. Collected by C. J. Norwood.*"

An irregularly laminated clay, mottled with grey of various tints, and ferruginous infiltrations. Has some imperfect vegetable impressions, and minute glimmering specks of mica.

No. 2076—"CLAY, *from Bald Knob Church, Caney precinct, on the Pinchico road, about two feet below a coal bed. Collected by C. J. Norwood.*"

In friable lumps, showing imperfect and irregular stratification. Of a light bluish-grey color, with infiltrations of ochreous and ferruginous, occasionally nearly black, especially in the cracks and along the course of rootlets which have penetrated it. Before the blow-pipe it appears to be quite refractory, not fusing, but softening and shrinking somewhat into a hard, porcelain-like, nearly white mass. When not so intensely heated it burns of a light salmon color.

COMPOSITION OF THESE OHIO COUNTY CLAYS, DRIED AT 212° F.

	No. 2074.	No. 2075.	No. 2076.
Silica	69.260	70.860	62.760
Alumina	16.640	19.240	26.420
Iron oxide	4.520	3.120	1.580
Lime	a trace.	a trace.	.325
Magnesia	.893	.425	a trace.
Phosphoric acid	a trace.	a trace.	not est.
Potash	3.102	2.351	.916
Soda	.210	.253	.268
Water and loss	5.375	3.751	7.731
Total	100.000	100.000	100.000

No. 2076 contains 5.3 per cent. of fine transparent colorless sand grains. This seems to be a very good fire-clay.

OLDHAM COUNTY.

SOILS.

No. 2077—"VIRGIN SOIL, *from the surface, and to the depth of thirteen inches. From the farm of Dr. Coy Kaye, Pewee Valley. Upper Silurian formation. Forest growth: beech, oak, poplar, black gum, &c. Soil better than usual in this locality. Collected by John H. Talbutt.*"

Dried soil, of a brownish-grey color; friable; contains no gravel. Its silicious residue all passed through the bolting-cloth.

No. 2078—"SUBSOIL *of the preceding,*" *&c., &c.*

Dried subsoil of a bright brick color, somewhat cloddy. Contains no gravel. The bolting-cloth separated, from the silicious residue, a very few small rounded quartz grains.

No. 2079—"SURFACE SOIL, *from white oak land, Pewee Valley. Collected by A. W. Kaye.*" *Uncultivated.*

The dried soil is in friable clods, of a dark umber-grey color. Contains no gravel. The silicious residue, left after digestion in acids, all passed through the bolting-cloth, except a few small milky quartz grains.

No. 2080—"SUBSOIL *to the preceding,*" *&c., &c.*

The dried subsoil is generally of a dark, orange-buff color, mottled with light grey and ferruginous. It contains some nearly black concretions and infiltrations. The clods are somewhat firm. It contains a few small fragments of weathered chert. The bolting-cloth separated, from the silicious residue, some hard particles—reddish and white—of undecomposed silicates, resembling felspar.

* COMPOSITION OF THESE OLDHAM COUNTY SOILS, DRIED AT 212° F.

	No. 2077.	No. 2078.	No. 2079.	No. 2080.
Organic and volatile matters	4.612	3.016	4.215	3.250
Alumina and iron and manganese oxides	4.449	8.882	5.010	9.008
Lime carbonate	.145	.195	.245	.220
Magnesia	.313	.304	.250	.178
Phosphoric acid	.141	.098	.125	.077
Sulphuric acid	not est.	not est.	not est.	not est.
Potash	.388	.521	.138	.349
Soda	.055	.117	.035	.330
Water, expelled at 380° F.	.713	.607	1.535	1.150
Sand and insoluble silicates	88.665	86.465	88.240	84.825
Total	99.481	100.205	99.793	99.387
Hygroscopic moisture	1.900	2.875	1.850	3.300
Potash in the insoluble silicates	1.281	1.109	1.428	1.088
Soda in the insoluble silicates	.381	.444	.663	.022
Character of the soil	Virgin soil.	Subsoil.	Surface soil	Subsoil.

Soils Nos. 2077, 2078, and 2080 are exceptionally rich in potash; the other contains an average amount. The subsoils in both samples are somewhat deficient in phosphoric acid. These may be classed as good rich soils, but their productiveness might be improved and maintained by increasing their proportion of *humus* in a rotation of crops, and by the use of phosphatic fertilizers. It is also probable that plaster of Paris on the clover crop may be beneficial on soils Nos. 2077 and 2078.

TRIGG COUNTY.

No. 2081—"LIMONITE *iron ore. From a bank one mile south of Centre Furnace. Average sample, by P. N. Moore.*"

This ore is mostly in dense, hard, irregular hematitic layers, dark brown and nearly black, with but little of the softer ochreous ore.

COMPOSITION, DRIED AT 212° F.

Iron peroxide	71.708	= 50.195 per cent. of iron.
Alumina and manganese oxide	.945	
Lime carbonate	trace.	
Magnesia	trace.	
Phosphoric acid	.217	= .095 per cent. of phosphorus.
Sulphuric acid	trace.	
Combined water	9.630	
Silicious residue	17.280	= 16.960 per cent. of silica.
Total	99.780	

This is quite a rich and pure ore, which would doubtless produce a very tough iron, provided the fuel and flux employed in the smelting process are free from sulphur and phosphorus.

PIG IRONS OF CENTRE AND TRIGG FURNACES, TRIGG COUNTY.

No. 2082—"PIG IRON No. 1. *Foundry iron. From Centre Furnace. Collected by P. N. Moore.*"

A moderately coarse-grained grey iron. Yields readily to the file. Large fragments of it break readily, but the smaller ones extend considerably under the hammer.

No. 2083—"PIG IRON No. 2. *Foundry iron. Centre Furnace. Collected by P. N. Moore.*"

Somewhat finer grained than the preceding, especially on the outer surfaces, and a little lighter colored. Yields readily to the file, and extends considerably under the hammer.

No. 2084—"PIG IRON No. 3. *Mill iron. Centre Furnace,*" *&c., &c.*

Lighter colored, finer grained, and more brittle than the preceding.

No. 2085—"PIG IRON. *Mill iron. From Trigg Furnace,*" *&c., &c.*

Quite a fine grained grey iron. The small fragments extend considerable under the hammer. Yields to the file.

No. 2086—"PIG IRON. *Silver Grey. From Trigg Furnace, &c. Collected by P. N. Moore,*" as were also the above described.

Hard; easily splintered on the edges. The small fragments extend very little, before breaking, under the hammer.

COMPOSITION OF THESE CENTRE AND TRIGG FURNACE PIG IRONS.

	No. 2082	No. 2083.	No. 2084.	No. 2085.	No. 2086.
Specific gravity	6.872	7.027	7.183	6.934	6.864
Iron	92.349	92.953	93.946	91.173	89.576
Graphite	3.380	3.140	2.860	3.400	1.000
Combined carbon	. . . . .	1.010	1.060	. . . . .	1.380
Aluminum and manganese	not est	not est.	not est.	not est.	not est.
Silicon	3.794	2.641	1.932	4.592	6.637
Slag	.660	.100	.360	1.160	1.560
Phosphorus	.318	.318	.276	.262	.221
Sulphur	.067	.074	.104	.094	.121
Total	100.568	100.236	100.538	100.681	100.495
Total carbon	3.380	4.150	3.920	3.400	2.380

These are all good samples of pig iron. The mill iron does not contain enough phosphorus to prevent it from producing good tough bar iron by judicious puddling.

WARREN COUNTY.

No. 2087—"MINERAL WATER. *Sulphur water. From a bored well two hundred and thirty feet deep. Smith's Grove, one hundred miles from Louisville, on the Louisville and Nashville Railroad. Sent by Junius Wooten, M. D.*"

The water was brought in tightly corked bottles, but when it arrived at the laboratory the hydrogen sulphide had all been decomposed; it was slightly opalescent, probably from the consequent precipitation of sulphur. It is slightly alkaline.

As there was an insufficient quantity of the water, a complete analysis could not be made; but from the preliminary examination of it, the following provisional summary of its composition is given: hydrogen sulphide gas, quantity not estimated; carbonic acid gas, not estimated.

SALINE CONTENTS.

Lime carbonate	0.1445	Dissolved by the carbonic acid.
Magnesia carbonate	.0177	
Strontia carbonate	not est.	
Lime sulphate	.0998	
Magnesia sulphate	.2856	
Potash sulphate	.0041	
Soda sulphate	.0213	
Sodium chloride	.0520	
Lithium chloride	not est.	
Soda carbonate	.0381	
Silica	.0022	
Ingredients undetermined and loss	.2547	
Saline ingredients in 1000 parts	0.7200	

It is desirable that a more thorough analysis should be made of this water, which seems to be a good saline sulphur water, which may be made serviceable in the treatment of various ailments.

This well is within six miles of the Chalybeate and Chameleon Springs of Edmonson county, and its use is said by Dr. Wooten to be beneficial in dyspepsia and indigestion, &c. The spectroscope showed in it traces of lithium and strontium compounds.

APPENDIX.

TEXAS CRETACEOUS SOILS.

With a view to comparison with our Kentucky soils, some of the black soils from the cretaceous formation of Texas were analyzed.

No. 2088—"BLACK SANDY SOIL. *From three miles northwest of Sherman, Grayson county, Texas. Prairie soil, in cultivation. Collected by Mr. Jesse H. Talbutt.*"

A dark, mouse-colored sandy soil, containing many fragments of roots, &c. The silicious residue, after digestion in acids, all passed through the bolting-cloth, except a small quantity of colorless, transparent, rounded grains of quartz.

No. 2089—"SOIL. *From 'black waxy' land, half a mile east of Sherman, farm of H. H. Allen. Prairie land. Collected by Mr. Jesse H. Talbutt.*"

Quite an adhesive soil; in clods; of a greyish-black color. The silicious residue all passed through the bolting-cloth.

No. 2090—"SOIL. *From 'black waxy' land, H. M. Stone's, two miles west of Playno, Collins county, Texas. Prairie land, in corn. Collected by Mr. Jesse H. Talbutt.*"

Not quite so black as the preceding; not in clods; friable. Effervesces strongly with acids.

COMPOSITION OF THESE TEXAS SOILS, DRIED AT 212° F.

	No. 2088.	No. 2089.	No. 2090.
Organic and volatile matters	4.977	7.233	7.097
Alumina and iron and manganese oxides	2.616	8.157	11.447
Lime carbonate	.880	1.745	17.085
Magnesia	.169	.223	.231
Phosphoric acid	.124	.083	.143
Sulphuric acid	not est.	not est.	not est.
Potash	.078	.211	.497
Soda	.052	.051	. . . . .
Water, expelled at 380° F.	.799	1.391	1.660
Sand and insoluble silicates	89.690	80.690	61.840
Total	99.385	99.784	100.000
Hygroscopic moisture	3.075	0.665	0.850
Potash in the insoluble silicates	0.670	0.764	0.443
Soda in the insoluble silicates	.322	.159	.307
Character of the soil	Bl'k sandy.	Bl'k waxy.	Bl'k waxy.

These Texas prairie soils differ from most of our Kentucky soils in their smaller proportion of alkalies in the silicious residue; they also present a larger quantity of carbonate of lime, which is very large in soil No. 2090, and which helps to give the waxy character to the land. The so-called black sandy soil is quite deficient in potash, and would not prove durably productive without the continued use of fertilizers. The richest of them all is No. 2090. The rock substratum to these

soils is an indurated chalk, the imperfect analysis of which is given below.

No. 2091—"INDURATED CHALK ROCK. *From near Sherman, Texas. Collected by Mr. Jesse H. Talbutt.*"

A whitish, somewhat friable rock, stained irregularly with light ferruginous. Adheres firmly to the tongue.

COMPOSITION, DRIED AT 212° F.

Lime carbonate	86.270
Magnesia carbonate	trace.
Alumina and iron and manganese oxides	2.980
Silicious residue	10.276
Alkalies, phosphoric acid, &c.	not det'd.
Total	99.526

No doubt the action of the large quantity of carbonate of lime, derived from this soft substratum, in gradually decomposing the silicates of the soil, is the cause of the rather small proportion of the alkalies in the insoluble silicates of the silicious residue.

CHEMICAL EXAMINATION OF THE ASHES OF THE HUNGARIAN GRASS (PANICUM GERMANICUM) AND GERMAN MILLET (PANICUM ———).

No. 2092—"HUNGARIAN GRASS (*black-headed*), *taken roots and all, the leaves being nearly all green, and the seeds in the soft or doughy state. Plants about three feet high, in the condition in which they are generally mown for hay.*"

The field on which they were grown had been in winter rye, which had been all grazed down by cattle, and the cattle had been fed with corn fodder on the ground during the winter. The grass had been sown about the first of June, 1875, and it was mown August 9th to 13th. Rich blue-grass soil. Farm of R. Peter, Newtown Turnpike.

The quantity taken for analysis; weighing 524 grammes in the green state, after washing it in the evening and subsequent drying through the night; grew on less than a square foot of surface, and when thoroughly air-dried weighed 182 grammes, or 34.751 per cent. of the green plants.

No. 2093—"HUNGARIAN GRASS, *same variety as the preceding. From the adjoining farm of Mr. C. M. Keiser; gathered June 27th*, 1876.

Plants three to three and a half feet high. The heads just forming.

No. 2094—"GERMAN MILLET. *From a field of ten acres, just outside the city limits of Lexington, on the Newtown Turnpike; property of Mr. J. K. Drake.*"

This field has been fully seventy-six years in cultivation, mostly in corn and garden stuffs, with occasional small grain. Five years ago it was manured with seventy-five cart-loads of stable manure to the acre, and sowed in clover, which was allowed to remain until last year, when the ground was put in hemp, which was rotted on the same surface. The clover was mowed only one year, and in the other years very few cattle were grazed on it; so that most of it rotted on the ground. The German millet sown this year, 1875–'6, gave seventeen stacks, estimated at two tons each, of hay, equal to more than three tons to the acre. The grass grew nearly five feet high, and was coarse and hard in the stalks. The sample, gathered about the time of mowing it, August 28th, had its heads heavy with ripe seed; lower leaves dead.

In the green state it weighed two hundred and four grammes. After two months air-drying in the laboratory it weighed ninety-six and a half grammes, of which there were thirty-seven grammes of seed. The stalks and leaves were incinerated separately from the seeds.

No. 2095—"THE SEEDS *of the above described sample.*"

For comparison, the analysis of the ash of the buckwheat and clover plants are appended (the latter in Table II), copied from a memoir by the writer (in volume II, pages 157, 158 (lower paging), Kentucky Geological Reports, second series).

TABLE I. COMPOSITION, CALCULATED IN 100 PARTS OF THE ASH. CARBONIC ACID EXCLUDED.

	No. 2092.	No. 2093.	No. 2094.	No. 2095.	Vol. 2, p. 158,* second series, Geological Reports.
	Hungarian grass.	Hungarian grass.	German millet, stalks and leaves.	German millet, seeds.	Buckwheat plants in flower
Lime	0.957	0.937	11.330	7.711	33.434
Magnesia	.490	1.260	3.237	6.916	10.518
Alumina and iron and manganese oxides	2.090	3.378	3.624	1.690	not est.
Potash	21.724	47.707	32.609	24.265	32.900
Soda	.167	.135	.474	......	1.266
Phosphoric acid	9.170	10.033	10.776	16.994	16.824
Sulphuric acid	.811	2.008	.717	.578	1.378
Chlorine	.097	2.620	.243	.319	.431
Silica, soluble	1.914	.254 }			{ 3.249
Silica, insoluble	61.835	31.609 }	37.070	40.387	{ ......
Total	99.265	99.941	100.080	98.860	100.000
Percentage of ash to dried plants	8.067	6.461	4.968	2.505	8.762
Percentage of ash to green plants	2.802	not est.	2.350	....	1.577
Percentage of dried to green plants	34.751	not est.	47.300	....	18.000

* The lower paging.

TABLE II. COMPOSITION OF THE ASH OF THESE PLANTS, SEEDS, &c. CARBONIC ACID EXCLUDED. CALCULATED IN 100 PARTS OF THE DRIED PLANTS, &c.

	No. 2092.	No. 2093.	No. 2094.	No. 2095.	Vol. 2, p 158,* second series, Ky. Geological Reports.	Vol. 2, p 157,* second series, Ky. Geological Reports.
	Hungarian grass.	Hungarian grass.	German millet, stalks and leaves.	German millet, seeds.	Buckwheat plants in flower	Clover plants.
Lime	0.076	0.060	0.562	0.193	2.929	2.30
Magnesia	.040	.082	.161	.173	.922	.80
Alumina, iron and manganese oxides	.168	.218	.180	.042	....	....
Potash	1.752	3.082	1.619	.608	2.883	2.30
Soda	.013	.009	.023	....	.111	.10
Phosphoric acid	.738	.648	.535	.426	1.470	.65
Sulphuric acid	.065	.130	.037	.015	.120	.20
Chlorine	.007	.169	.012	.008	.038	.25
Silica, soluble	.155	.016 }			{ .285	.20
Silica, insoluble	5.069	2.042 }	1.842	1.012	{	....

* The lower paging.

It can be seen in these tables that the ash of the Hungarian grass, as well as that of the German millet, is remarkably silicious, and that a large portion of the silicious matter is in the insoluble condition.

At first, it was supposed that, although care had been taken to wash the plants thoroughly, much of this silicious matter might be excluded from the results of the analyses, as sand accidentally derived from the soil, and adherent as dust to the plants; but a more thorough examination, with the aid of the microscope, in the hands of our experienced microscopist, Mr. Alexander T. Parker, showed that much of it was in the form of a silicious skeleton of the plant tissue. This fact was made more manifest by digesting portions of the stem and leaves in diluted nitric acid, with and without the addition of chlorate of potash, until the organic matters were mostly decomposed and removed, when beautiful silicious skeletons were obtained, which, under the microscope, showed silicious casts or incrustations of the vegetable cells, and curious dumb-bell forms, proving that the silicious matter, in a dissolved state, had penetrated through the cell walls, and changing into the insoluble form, had incrusted the interior of the cells.

Some beautiful photographs were obtained by Mr. Parker, with the aid of our skilled photographer, James Mullen, directly from the enlarged microscopic images formed from the silicious residue, after digestion in the acid and subsequent ignition to destroy all the organic matters. The German millet gave fewer of the dumb-bell-like casts than the Hungarian grass, and the seeds of the former less than any.

DESCRIPTION OF THE MICROSCOPIC PHOTOGRAPHS.

No. 1. Silicious material of the stem of Hungarian grass, which had been digested for several days in nitric acid diluted with six parts of water, to which chlorate of potash was added and thorough washing. Magnified about 312 diameters, and photographed by Alex. T. Parker.

No. 2. A similar preparation from the leaf of this plant. Magnified about 312 diameters, and photographed by Alex. T. Parker.

These photographs of the purely silicious skeletons of the tissue of the vegetable leaf and stem are interesting as exhibiting casts of the cells, produced, no doubt, by the infiltration

of dissolved silicic acid, as also as showing, in their dumb-bell shapes, these cells apparently in the act of multiplication by the process of division.

It is well known to chemists that silica, in its ordinary separated state in the soil, is almost completely insoluble in water or the ordinary acids; but it is also well known that it takes the unstable soluble form of silicic acid when separated, by the decomposition of silicates by the action of acids in the presence of water. Doubtless the acid sap of the plants, coming in contact with the silicates of the soil, by osmose, caused this decomposition, and the relative amount of the silicious incrustation of the plant cells may give some measure of this local individual plant action on the soil.

It is well known the Hungarian grass is a very vigorous growing plant, even on soils comparatively poor, and that it is a very rough feeder, seeming to have greater power of assimilating insoluble, or difficultly soluble, soil ingredients than most other cultivated plants. Moreover, as is seen, it is eminently silicious. All these facts seem to show that it in some manner dissolves or decomposes the silicates of the soil in a greater degree than is common to most growing vegetables.

It has been known for a length of time that certain vegetables, especially of the lichen family, corrode the limestone, or even the basaltic or granitic rock or glass, on which they grow, and that, as was ascertained by Braconnet, some of these plants are known to contain oxalate of lime to the extent of half their weight. Other plants, as those of the lycopodium family, possess the power of dissolving and absorbing alumina by means of malic acid which they produce; so that the compound of this earth, so rarely found in vegetable tissue, is present in them in large proportion. That the roots of most plants, while alive or growing, give an acid reaction, is well known, and easy to verify by placing them in contact with blue litmus paper or infusion; but what is the nature or relative quantity of the acid or acids secreted by the various species of vegetables, or how they may act on the soil to decompose it, and in what manner their action may modify the ash composition of the several plants, has not as yet been made a subject of systematic investigation.

It is well known that plants of different species, growing in precisely the same soil, will vary greatly in their mineral or ash constituents; and the late Baron Liebig was perhaps the first to declare (see Natural Laws of Husbandry, edited by John Blyth, M. D., New York, 1863, page 118) that "plants receive their food principally from the earthy particles with which the roots are in direct contact, out of a solution forming around the roots themselves." This solution, other things being equal, will vary according to the nature and quantity of the solvent, which solvent seems to be provided by the plants themselves, and secreted by the roots, and is evidently of an acid nature.

It is beginning to be generally understood that different plants secrete this acid solvent of the soil in different quantities, and probably of different strength and composition. Some of them, like the lichens which grow on the rock or lava surface, being able, by their special solvents, to extract their essential mineral elements from the hard material, which they thus decompose, while others, not being able to exert such a powerful decomposing and corroding agency, can only live on more soluble and available materials, which they may find in the decomposing remains of these pioneers of the vegetable world, or in solution in fertile soils generally.

To these special solvents—these peculiar digestive fluids of the vegetable kingdom—may very probably be attributed, in some measure, the special selective power of plants, by which different species, growing on the same soil, will appropriate to themselves not only very different quantities of the mineral elements, but different kinds of these matters; so that while one plant may be characterized by a large proportion of potash in its ash ingredients, another may always select a very large amount of lime, and yet another an unusual quantity of silica, &c., &c., and, practically, when a soil will no longer profitably produce one crop, it may yet be quite productive of another.

Some experiments of Dietrich, quoted in Johnson's "How Crops Feed" (pages 327–8), illustrate very clearly the different action of different plants in this relation. He caused these to grow in coarsely powdered sandstone and basalt rock, severally, watering them with equal quantities of distilled water, &c. He took also similar quantities of the same rocks and washed them with the same amount of the water, in order to exclude the mineral materials dissolved out of the rocks by the water alone. The special and very different solvent and decomposing action of the several plants on the rock materials is clearly shown in the following table, which we quote:

MATTERS DISSOLVED BY ACTION OF ROOTS.

	On 9 lbs. of sandstone.	On 11 lbs. of basalt.
Of 3 lupin plants	0.608 grams.	0.749 grams.
Of 3 pea plants	.481 "	.713 "
Of 20 spurry plants	.268 "	.365 "
Of 10 buckwheat plants	.232 "	.327 "
Of 4 vetch plants	.221 "	.251 "
Of 8 wheat plants	.027 "	.196 "
Of 8 rye plants	.014 "	.132 "

The three pea plants extracted from these hard rocky materials more than forty times as much as the eight rye plants, and nearly twenty times as much as the eight wheat plants, under the same external conditions.

From the large proportion of ash ingredients in the Hungarian grass, and especially of silica, and its rank growth, it was considered probable by the present writer that it exerted an unusually great "root action" on the soil, by means of an acid solvent. To verify this supposition, some of this grass was gathered by him early in July, 1877, just as it was beginning to form its heads, and submitted to examination. The moistened roots, placed in contact with blue litmus paper, reddened it decidedly. A handful of the entire plants, which had been pulled up by the roots, the dirt having been shook off as completely as possible, was placed with the roots immersed in a saturated cold solution of carbonate of ammonia, and allowed to remain for twenty-four hours. The solution, which had become of a light brown color, was then evaporated to dryness at a heat below 212° F. It left a dark brown residue, which was re-dissolved in water, filtered and precipitated with a solution of acetate of lead and a little ammonia. This precipitate, after washing with cold water, was suspended in water and decomposed with hydrogen sulphide, &c., and the filtrate, still somewhat colored, was tested for acids in the usual manner. It was found that oxalic and phosphoric acids were present in marked quantities, together with some malic acid, and probably a small amount of tartaric. Tannic acid was not observed.

Some of the same grass was gathered July 23d, when the seeds were beginning to ripen, and submitted to the same process, with very nearly the same results; the oxalic and phosphoric acids being found in largest proportions.

Some *buckwheat* plants, gathered on September 4th and 6th, when they were in full flower, were treated in a similar manner. Two handfuls of the plants were placed, successively, with roots immersed in the same saturated solution of carbonate of ammonia, each being allowed to remain in it twenty-four hours. The solution, which became also of a brownish color, treated in the manner above described, gave marked evidence of the presence of oxalic and phosphoric acids, with a notable quantity of malic acid, and small proportions of other vegetable acids; but no tannic acid could be detected with iron perchloride. The buckwheat roots did not react so decidedly acid with litmus paper as those of the Hungarian grass.

Although in these experiments the strong chemical affinity of the alkaline carbonate of ammonia may have caused the exosmose of more of the dissolved acids of the plant-sap than would pass out into any ordinary soil, and may have even exerted some decomposing action on the soft tissues or the fluids of the plants themselves, yet they are not without some value as indicating how, possibly, the plant may form a special solution, different probably for different species, in the immediate vicinity of the rootlets, of mineral substances in the soil which

may be insoluble in the ordinary surface waters. Researches into the nature of the special soil solvents of different plants may aid the practical farmer in the selection of crops in an ameliorating rotation, as it seems highly probable that some kinds of vegetables can exert a more powerful decomposing action on the silicates of the soil than others.

TABLE I. SOILS, SUBSOILS, UNDER-CLAYS, &c., DRIED AT 212° F.

Number in Report.	County.	Organic and volatile matters.*	Alumina and iron and manganese oxides.	Lime carbonate.	Magnesia.	Phosphoric acid.	Potash	Soda.	Sand and insoluble silicates.	Water, expelled at 380° F.	Water, expelled at 212° F.	Potash in the insoluble silicates.	Soda in the insoluble silicates.	Remarks.
1967	Allen	2.215	3.616	0.110	0.106	0.019	0.144	0.489	92.980	0.650	0.950	0.992	0.253	Virgin soil, Buncombe tract.
1968	Allen	2.045	5.872	.030	.097	.013	.160	.312	90.840	.615	1.250	.958	.209	Subsoil of the above.
1969	Allen	5.475	5.629	.520	.124	.156	.148	.210	85.740	2.200	2.425	.958	.314	New upland soil, W. H. H. Mitchell's.
1970	Allen	4.000	7.394	.470	.097	.141	.380	.175	85.090	1.625	2.215	.853	.242	Subsoil to the same.
1971	Allen	2.745	5.452	.070	.079	.083	.221	.143	90.440	.865	1.175	1.081	.354	Old field, same locality, &c.
1972	Allen	2.450	8.090	.080	.140	.045	.219	.115	88.040	.850	1.550	1.188	258	Subsoil to the same.
1973	Barren	4.175	7.365	.215	.197	.125	.209	. . . .	86.065	1.575	1.865	1.227	.394	Virgin soil, barrens, Maj. J. S. Barlow.
1974	Barren	5.475	7.740	.465	.250	.275	.126	.004	82.990	2.275	2.500	1.074	.334	Old field, same locality, &c.
1975	Barren	2.615	8.323	.090	.197	.092	.308	. . . .	86.665	.935	1.775	1.253	.373	Subsoil of the two preceding
1976	Barren	5.465	4.310	.340	.047	.125	.184	.029	87.470	1.800	2.150	.934	.300	Virgin soil (silicious grit), D. Davasher's.
1977	Barren . . .	3.065	4.942	.225	.065	.093	.158	.053	90.185	1.015	1.500	1.102	.318	Old field, same locality.
1978	Barren	2.300	6.142	.125	.080	.093	.092	.055	89.985	.800	1.700	1.179	.256	Subsoil of the next preceding.
1979	Barren	4.700	4.632	.425	.061	.108	.069	.060	87.985	1.650	2.100	.722	.234	Virgin soil (silicious grit), Mrs. M. E. Davis
1980	Barren	3.450	4.622	.190	.061	.198	.126	.024	89.685	1.300	1.650	1.223	.381	Old field, same locality, &c.
1981	Barren	2.415	6.186	.190	.065	.124	.225	.086	89.650	1.000	1.735	1.151	.318	Subsoil of next preceding.
1982	Barren	4.150	5.967	.475	.017	.093	.105	. . . .	87.710	1.325	1.800	1.156	.372	Old field, bottom land, same locality.
1983	Barren	3.725	6.034	.475	.115	.131	.161	. . . .	87.835	1.375	1.900	1.127	446	Subsoil of next preceding.
1999	Fayette	4.325	12.168	.295	.214	.492	.268	.038	80.090	1.800	2.850	1.343	.359	Surface soil, lawn at Ashland.
2000	Fayette	3.535	15.666	.345	.331	.604	.372	. . . .	77.715	1.300	3.375	1.273	.332	Subsoil of the same.
2008	Grant	5.515	13.849	1.420	.513	.636	.952	.082	77.640	Included in the water and organic matters lost on ignition.	5.710	2.524	.499	Subsoil, cut at station 295, section 29, C. S. R. R.
2009	Grant	5.400	12.675	1.465	.600	.435	.780	.617	78.965		5.950	2.511	1.214	Under-clay (hard pan?), same locality.
2010	Grant	5.425	6.847	.200	.420	.188	.568	.317	86.165		2.750	1.687	.388	Top soil, old fi'd, cut, st'n 30, sec. 30, C. S. R. R.
2011	Grant	4.100	9.199	.190	.420	.086	.156	.368	85.460		3.400	1.958	.260	Subsoil of same.
2012	Grant	4.450	11.672	.165	.398	.188	.579	.104	82.490		3.825	1.533	.638	Subsoil, just under next preceding.
2013	Grant	5.600	12.564	.225	.609	.236	.259	.246	80.115		5.950	2.004	397	Under-clay, just under next preceding.
2014	Grant	4.950	15.237	2.290	.383	.823	1.124	.019	75.240		6.575	2.410	407	Under-clay, just under next preceding.
2015	Grant	4.425	24.465	9 425	.286	.589	.669	.245	59.940		5.250	2.703	.265	Under-clay, just below next preceding.
2016	Grant	4.365	17.502	1.115	.151	.473	.809	.052	75.090		not est.	1.542	.297	Subsoil, section 33, second cut from north end.
2017	Grant	4.675	27.353	4.555	.266	.457	1.585	.125	60.967		not est.	1.487	.212	Under-clay, same locality.
2018	Grant	5.675	9.540	.575	.312	.345	.587	. . . .	83.790		not est.	1.679	.510	Surface soil, sec. 34, second cut from south end.
2019	Grant	3.780	10.222	.290	.266	.313	.150	. . . .	84.890		not est.	1.881	.552	Subsoil, same locality.
2020	Grant	6.290	18.593	.275	.402	.393	.611	.165	73.575		not est.	1.489	.486	Under-clay, same locality.
2021	Grant	6.085	15.437	1.225	.679	.473	.809	066	75.890		not est.	2.428	.376	Under-clay, below last, same locality.
2022	Grant	4.290	11.792	8.240	.824	.793	1.778	.359	71.924		not est.	2.423	.324	Under-clay, just below preceding.
2023	Grant	4.650	7.225	.470	.303	.185	.738	. . . .	87.065		not est.	1.812	.722	Top soil, sec. 35, cut at north end, C. S. R. R.
2024	Grant	3.940	9.852	.390	.447	.358	.282	. . . .	84.760		not est.	1.673	.677	Subsoil, same locality.
2025	Grant	5.400	16.827	1.640	.645	.358	.213	.337	75.040		not est.	2.103	.433	Under-clay, same locality.
2026	Grant	4.450	14.492	2.315	.609	.358	.760	. . . .	77.440		not est.	2.851	.417	Under-clay, below preceding.
2027	Grant	5.025	21.124	4.305	.420	.361	.210	.308	68.515		not est.	2.700	.378	Under-clay, next below preceding.
2028	Grant	5.850	23.100	3.640	.223	.505	.534	. . . .	66.390		not est.	2.865	.449	Under-clay, under preceding.
2029	Grayson. . . .	3.239	3.096	.020	.097	.144	.160	.268	91 865	.506	1.200	.927	.262	Virgin soil, over the Leitchfield marl.
2030	Grayson. . . .	2.534	4.781	.045	.061	.159	.100	.102	91.490	.483	1.575	1.198	.254	Subsoil to the same.
2034	Hardin	4.495	5.579	.340	.286	.071	.149	.037	87.675	1.675	1.900	1.250	.435	Virgin soil, St Louis limestone, Gov. Helm's.
2035	Hardin	2.575	6.520	.215	.227	.070	.119	. . . .	89.140	.950	1.510	1.037	.376	Old field soil, same locality.
2036	Hardin	2.350	9.807	.140	.223	.083	.270	. . . .	85.590	.925	2.050	.848	.265	Subsoil of the two preceding.
2037	Hardin	9.185	8.705	1.350	.124	.203	.595	.011	77.905	2.715	2.885	2.910	1.166	Virgin soil, St. Louis Group, J. W. Fowler's.
2038	Hardin	5 400	8.228	.625	.107	.172	.279	.018	83.090	2.075	2.315	2.226	.782	Old field, same locality.
2039	Hardin	4.500	8.347	.465	.142	.123	.175	.077	84.440	2.000	2.265	1.137	.733	Subsoil of preceding
2040	Hardin	4.610	6.033	.390	.070	.102	.316	.098	86.355	1.625	1.815	.956	.197	Virgin soil, St Louis Group, Vandecraft's.
2041	Hardin	3.085	6.597	.290	.040	.038	.035	.025	88.940	1.150	1.335	1.302	.443	Old field, same locality.
2042	Hardin	3.550	11.254	.215	.025	.061	.251	.168	83.490	1.550	2.575	1.329	.256	Subsoil of the preceding.
2044	Hopkins . . .	2.850	4.952	.080	.106	.083	.145	.050	90.540	.737	1.085	1 693	.687	Virgin soil, woods, Mr. Miles'
2045	Hopkins . . .	2.090	6.883	trace.	.181	.077	.307	. . . .	89.700	.660	1.285	1.458	.697	Subsoil of preceding.
2049	Logan.	2.900	3.247	.395	.115	.093	.132	. . . .	92.350	.875	1.435	.890	.301	Virgin soil, bottom land, W. Morton's.
2050	Logan.	2.585	7.095	.210	.196	.115	.169	. . . .	88.755	.765	2.385	1.334	.357	Subsoil to next preceding soil.
2051	Logan.	2.560	5.297	.195	.160	.093	.121	.068	90.935	.765	1.550	1.286	.299	Old field soil, same locality.
2052	Logan.	3.925	8.315	.640	.346	.125	.060	. . . .	85.035	1.275	2.675	1.212	.353	Black soil, unproductive, H. B. Tully's.
2053	Logan.	3.675	11.811	.245	.227	.109	.212	.015	82.365	.950	3.800	1.349	.266	Subsoil, St. Louis limestone, same locality.
2054	Logan.	2.775	4.812	.180	.170	.093	.085	. . . .	91.090	.600	1.250	1.474	.532	Old field soil, same locality.
2055	Logan.	3.048	9.158	.180	.214	.077	.326	.050	86 275	.775	2.525	1.320	.265	Subsoil, from same locality.
2060	Madison . . .	5.825	10.434	.615	.043	301	.379	.094	79.965	2.415	3.165	1.537	.300	Red Bud soil, Covington farm.
2061	McCracken . .	2.050	5.497	.115	.268	.093	.167	.171	90.940	1 000	1.425	1.700	.598	Surface soil, L. M. Flournoy's.
2062	McCracken . .	2.650	12.300	.190	.521	.115	.284	. . . .	82.490	1.000	4.000	1 605	.911	Subsoil of the same.
2063	McCracken . .	2.675	10.834	.190	.649	.061	.643	.087	83.865	1.000	3.425	1.427	.668	Under clay of the same.
2064	Meade	3.565	5.091	.095	.133	.109	.156	. . . .	89.725	1.000	1.600	1.297	.471	Virgin soil, sandstone, Waverly G'p, McCarty's.
2065	Meade	5.665	15.741	.070	.242	.140	.425	. . . .	75.825	1.335	4.265	1.540	.304	Subsoil of the same.
2066	Meade	3.600	11.604	.045	.538	.156	1.082	. . . .	82.125	.650	2.950	2.259	.150	Under-clay of the same.
2077	Oldham	4.612	4.449	.145	.313	.141	.388	.055	88.665	.713	1.900	1.281	.381	Virgin soil, Pewee Valley, Upper Silurian.
2078	Oldham	5.016	8.882	.195	.304	.098	.521	.117	86.465	.607	2.875	1.109	.444	Subsoil of the same.
2079	Oldham	4.215	5.010	.245	.250	.125	.138	.035	88.240	1.535	1.850	1.428	.663	Surface soil, white oak land, Pewee Valley.
2080	Oldham	3.250	9.008	.220	.178	.077	.349	.330	84.825	1.150	3.300	1.088	.022	Subsoil of the same.
	TEXAS SOILS.													
2088	Grayson. . . .	4.977	2.616	.880	.169	.124	.078	.052	89.690	.799	3.075	.670	.322	Black sandy soil, prairie, in cultivation.
2089	Grayson. . . .	7.233	8.157	1.745	.223	.083	.211	.051	80.690	1.391	.665	.764	.159	Black waxy soil, prairie land.
2090	Collins	7.097	11.447	17.085	.231	.143	.497	. . . .	61.840	1.660	.850	.443	.307	Black waxy soil, prairie land, in corn.

*Or loss by ignition after drying at 212°.

TABLE II. COALS, AIR-DRIED.

Number in Report.	County.	Specific gravity.	Hygroscopic moisture.	Volatile combustible matters.	Coke.	Total volatile matters.	Fixed carbon in the coke.	Ash.	Character of the coke.	Color of the ash.	Percentage of sulphur.	Remarks.
1995	Butler	not de'd	3.28	44.20	52.52	47.48	48.56	3.96	Spongy	Dark lilac-grey . .	3.060	Mining City Coal B'k, new op'ng, Mud Cr'k.
2031	Greenup. . . .	1.345	6.33	32.42	61.25	38.75	53.30	7.95	Dense spongy .	Light lilac-grey . .	1.277	Cane Cr'k Mine, new op'g, n'r Hun'w'l Fur.
2032	Greenup. . . .	1.344	5.77	33.28	60.95	39.05	52.40	8.55	Dense spongy .	Light lilac-grey . .	.900	Same locality (sample 2).
2033	Greenup. . . .	1.383	6.03	30.77	63.20	36.80	50.65	12.55	Dense spongy .	Light lilac-grey . .	1.458	Same locality (sample 3).
2058	Madison . . .	not de'd	3.57	36.53	59.90	40.10	55.77	4.13	Light spongy .	Light yellowish-grey	.749	Marshall Moran's Bank, Big Hill.

TABLE III. IRON ORES (LIMONITE ORES), DRIED AT 212° F.

Number in Report.	County.	Iron peroxide.	Manganese oxide. Alumina.	Lime carbonate.	Magnesia.	Phosphoric acid.	Sulphuric acid.	Combined water.	Silica and silicates.	Percentage of iron.	Percentage of phosphorus.	Percentage of sulphur.	Percentage of silica.	Remarks.
2056	Lyon.	66.192	1.393	trace.	trace.	0.185	trace.	10.000	22.910	46.320	0.079	trace.	21.820	From Hall's patch drift.
2057	Lyon.	68.162	1.763	trace.	trace.	.505	trace.	9.630	20.150	47.703	.220	trace.	19.060	From Skillian Bank.
2081	Trigg	71.708	.945	trace.	trace.	.217	trace.	9.630	17.280	50.195	.095	trace.	16.960	From one mile south of Centre Furnace.

TABLE IV. IRON ORES (CLAY IRON-STONES AND BLACK BAND ORES), DRIED AT 212° F.

Number in Report.	County.	Specific gravity.	Iron carbonate.	Iron oxide.	Alumina and manganese oxide	Lime carbonate.	Magnesia carbonate.	Phosphoric acid.	Sulphuric acid.	Silica and silicates.	Per cent. of iron.	Per cent. of phosphorus.	Per cent. of sulphur.	Per cent. of silica.	Bituminous matters and water.	Remarks.
2046	Jackson	not est	70.168	. . .	0.430	0.930	2.898	0.345	. . .	6.230	33.875	0.151	0.264	4.960	18.540	Black band ore, Coyle's Bank.
2069	Ohio	not est	60.012	not est	11.451	4.430	5.395	.377	trace.	17.280	29.557	.146	trace.	13.860	1.055	From Wm. Downe's Iron Mountain.
2070	Ohio	not est	69.117	not est	7.437	4.780	4.639	.786	.084	11.480	32.294	.343	.034	6.860	1.677	From Wm. Downe's Iron Mountain.
2071	Ohio	not est	48.211	9.227	7.307	5.880	4.298	1.805	.030	19.850	29.484	.475	.012	17.460	3.392	From Wm. Downe's Iron Mountain.

TABLE V. PIG IRONS.

Number in Report.	County.	Specific gravity.	Iron.	Graphite.	Combined carbon.	Manganese.	Silicon.	Slag.	Phosphorus.	Sulphur.	Total carbon.	Remarks.
2082	Trigg	6.872	92.349	3.380	. . . .	not est.	3.794	0.660	0.318	0.067	3.380	No. 1, foundry iron, Centre Furnace.
2083	Trigg	7.027	92.953	3.140	1.010	not est.	2.641	.100	.318	.074	4.150	No. 2, foundry iron, Centre Furnace.
2084	Trigg	7.183	93.946	2.860	1.060	not est.	1.932	.360	.276	.104	3.920	No 3, mill iron, Centre Furnace.
2085	Trigg	6.934	91.173	3.400	. . . .	not est.	4.592	1.160	.262	.094	3.400	Mill iron, Trigg Furnace
2086	Trigg	6.864	89.576	1.000	1.380	not est.	6.637	1.560	.221	.121	2.380	Silver-grey iron, Trigg Furnace.

TABLE VI. CLAYS, DRIED AT 212° F.

Number in Report.	County.	Silica.	Alumina.	Iron oxide.	Lime.	Magnesia.	Phosphoric acid.	Potash.	Soda.	Water, expelled at red heat.	Remarks.
2007	Franklin . . .	69.300	21.780		*0.158	0.331	0.060	2.351	0.585	5.435	Potter's clay, bottom land, near Frankfort.
2074	Ohio	69.260	16.640	4.520	trace.	.893	trace.	3.102	.210	5.375	Indurated clay, below coal F, mouth of Brush Creek.
2075	Ohio	70.860	19.240	3.120	trace.	.425	trace.	2.351	.253	3.751	Clay, coal measures, near Elm Lick.
2076	Ohio	62.760	26.420	1.580	.325	trace.	trace.	.916	.268	7.731	Clay, Bald Knob Church, Caney precinct.

*Carbonate.

TABLE VII. MARLY SHALES, &c., DRIED AT 212° F.

Number in Report.	County.	Silica.	Alumina.	Iron oxide, &c.	Lime.	Magnesia.	Phosphoric acid.	Potash.	Soda.	Water, carbonic acid, &c., and loss.	Remarks.
1994	Breckinridge .	66.960	15.626	8.380	0.493	0.677	0.154	3.295	0.628	3.787	Marly shale, Tar Hill, near Cloverport.
1996	Butler	51.660	15.560	7.680	7.269	.817	not est.	3.276	.293	13.445	Marly shale, below coal, Mud Creek Mines.

GEOLOGICAL SURVEY OF KENTUCKY.

N. S. SHALER, Director.

REPORT ON

THE LIMONITE ORES

OF

TRIGG, LYON AND CALDWELL COUNTIES,

KNOWN AS THE

"CUMBERLAND RIVER ORES."

BY WM. B. CALDWELL, Jr.

Part VIII. Vol. V. Second Series.

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INTRODUCTORY LETTER.

Professor N. S. SHALER, *Director Kentucky Geological Survey:*

DEAR SIR: The following report is a continuation of the former paper on Western Kentucky, and will close, for the present, work in that region. The next report will be on the Eastern Kentucky district—the coals and iron ores. In making the following report, I have dwelt upon the question of steel, because ores suitable for the manufacture of even common grades of steel are so rare in the United States, and especially south of the Ohio river. This renders an ore, which can be used, far more valuable than its percentage of metallic iron would indicate.

WM. B. CALDWELL, JR.

THE LIMONITE ORES OF TRIGG, LYON, AND CALDWELL COUNTIES, KNOWN AS THE "CUMBERLAND RIVER ORES."

These ores were mentioned in my general report on "Ores and Coals of Western Kentucky," a paper submitted in February, 1878. Since then, my time has been devoted to the chemistry and metallurgy of steel-making; and, with the opportunity of thoroughly investigating the use of brown ores for the purpose, I have been more than ever impressed with the importance to the State, and more especially to Western Kentucky and Louisville, of the ores of which this paper will treat. The region has already gained a reputation for excellent iron, particularly for boiler plate, and "Cumberland River Iron Works" and "Hillman's Boiler Iron" are well known; but the advantages of the district are not known. If so favored a region lay in Ohio, Pennsylvania, or any State north or east, great developments would have been made long ago, and many thousand tons of iron would be annually brought over the Elizabethtown and Paducah Road to Louisville.

This report is intended, as all the Survey reports are, to bring to public notice the undeveloped wealth of the State; but in this paper it is intended, especially, to call attention to the fact that, only one hundred and seventy-five miles from Louisville, are extensive deposits of an ore suitable for making steel, a fact which is undeniable, and that the iron made from it could be put down at Louisville at a less cost than such iron sells at Pittsburgh or elsewhere.

In order the more efficiently to show the character of the ore, quality of iron produced, etc., Trigg and Centre Furnaces will be discussed at some length; for here we have practical proof of the working of the ore, and of the excellent quality of pig and wrought iron made; but first, a general description of the district: The Tennessee and Cumberland rivers enter Kentucky only a few miles apart, and cross the State side by side to the Ohio. Between the rivers, and on the eastern bank of the Cumberland, from Tennessee down to Livingston county, just beyond the crossing of the Elizabethtown and Paducah Road, about thirty miles in length, lies the iron ore deposit.

The coal measures extend southward into Caldwell county, about five miles from Princeton, where there is a deposit of the ore; and on Caney creek, about fifteen miles from Princeton, several five-foot veins of excellent coal have been opened.

It would be useless here to do more than mention the fact that the coals of Western Kentucky are suitable for iron-making, and can be mined very cheaply; for they were fully discussed in the former paper, with numerous analyses of coal and coke, and figures showing cost of mining.

The ores are in great abundance on the river banks and on the railroad. At and near Kuttawa, the crossing of the Cumberland, on the property of Governor Charles Anderson, are several extensive beds or pockets of ore, which were once mined largely for a charcoal furnace run there by Mr. Kelly, now of Louisville.

The railroad cuts through a heavy deposit, and there are mines at distances varying from one half to three miles. These deposits are a fair average of the occurrence in the whole region. The ore seems to have been deposited in the form of "pot ore" and "kidney," and at some points as "pipe ore," in a clay and chert formation, but subsequently subjected to disturbances which have mixed the broken pots, etc., more or less intimately with the clay and chert. Whether this was the manner of formation or not, and what the nature of the disturbances was, whether simply upheavals or the natural disintegration from washing down of the strata, is of no moment here. The appearance of the beds indicates such a process, and this describes sufficiently well, to any one who has not seen them, the nature of the deposits; but, I must add, that the masses of ore, uncontaminated with clay or chert, are often very large, weighing sometimes tons, and that the

smaller lumps may be easily taken out free. The only drawback is, that a certain quantity of dead work must be done in removing the clay and chert. This, however, is not at all expensive.

As to the amount of ore in a bed or pocket, it would be impossible to calculate, as none of them have ever been exhausted; the part above ground being apparently all ore and clay, and the ore seeming to run down the surface to a considerable depth.

The extent to which this commingling of ore and chert has been carried on varies considerably in different deposits, and also in the same deposit; but the ore, when carefully mined, as it is for use, varies very little in composition, as several analyses in my previous paper, and further analyses below, will prove. Ascending the river, deposits of ore are found here and there along the river and railroad. Above Eddyville, a station on the river and railroad, there have been several charcoal furnaces—Monmouth, Fulton, etc., and lately Centre and Trigg.

The old furnaces made iron when there was but little communication with distant points, and ten tons a day was a very large yield, but it was cold-blast charcoal iron. It was common then to make large sugar-kettles, iron pots, and common castings by running the iron from the furnace directly into the moulds, and it was a profitable business.

In these days of hot-blast coke furnaces, making sixty tons, and even much more, a day, the iron business on a small scale scarcely pays; and the combination of practical with theoretical knowledge of furnaces and the working of metals has brought the industry so far forward that production exceeds consumption, although many new uses are found for iron every day. On account of this over-production the industry has suffered severely during the past five years, and only highly favored localities can succeed—localities combining the following advantages: Abundant supply of good cheap coal near cheap ore, limestone, and water, and with transportation facilities to a near and good market. Or for charcoal iron, which always brings a higher price for certain purposes, good cheap ore must lie in a well timbered country, with plenty of limestone and water, with the same requisite transportation facilities. Such localities exist in Western Kentucky for coke iron and for charcoal iron.

CHARCOAL IRON.

The furnaces referred to above—Centre and Trigg—will afford evidence of the adaptability for charcoal iron, excepting that transportation is not as cheap as it might be.

About ten miles above Eddyville are the boiler-plate works of D. Hillman & Sons, for which the furnaces in question were run, and which I will describe briefly after speaking of the furnaces.

TRIGG FURNACE.

This furnance is on the eastern bank of the Cumberland, about three miles inland, and five miles above the rolling mill just mentioned. It has been out of blast for some time, but is well kept, and in good condition.

The stack is large and well shaped, has closed top and down-take pipes for the gases, which are utilized for heating the blast. The hot-blast ovens are arranged so that they can be fired with fuel or with waste gases, or both. There is a good steam hoist for raising ore and fuel to the tunnel-head. Three horizontal blowing engines furnish blast, and these are well preserved. Altogether, the plant is in good condition, and would require but little work and repairing to start up again. The ore banks about the furnace are very extensive, and are only about one mile distant, the ore being brought by cars down grade on a narrow gauge tramway, and empty cars hauled back by mules. This ore is of the same general character as that in the other parts of the region, occurring in great beds, and more or less mixed with chert and clay. It requires very little mining, only being at all expensive on account of the dead work in removing clay and chert. Immense pits have been dug, leaving a bottom of ore, which

extends to a considerable depth below the general level, and these pits continued into the hill. The drawback to this method of mining is the water which accumulates, and for that reason it would, in the end, probably be economical to tunnel or drift into the hill, and then work passages off to the sides, and also to work down.

Mining it, however, as it was done, was very cheap, not costing over $1 10 to put the ore down at the furnace, and to keep it very clean and free from chert. This was the easier from the fact that the lumps of ore are individually quite free from impurity, and are often of great weight, so that when gotten out and broken up they need no further cleaning. As to quality, the ore is very similar to that already mentioned. On page 8 of the former report are several analyses of limonite ores from the district, and the following show the similarity, as also the excellent character of the ore.

1. Ore taken from bank worked for Trigg Furnace.

2. Ore taken from bank near by, which had also been worked.

	1.	2.
Iron oxide	70.31	69.93
Alumina	2.54	3.12
Lime	1.89	1.53
Magnesia	1.48	1.62
Water	10.70	10.21
Silica	12.91	13.45
Total	99.83	99.86
Metallic iron	49.210	48.950
Phosphorus	0.091	0.087

Limestone is abundant and good; and, being at hand, could not cost more than seventy-five cents per ton.

Good charcoal timber surrounds the furnace and ore banks, and, although the furnace has been worked for some years, the timber is not thinned out. I was told in the country there that contracts could readily be made to furnish charcoal at four and a half cents per bushel; but, putting it at five and a half cents a bushel, the fuel for a ton of iron would not cost over seven dollars. Labor is abundant and cheap, the native population being glad to get work; and then there are many negroes, already trained to the work, who make excellent furnace hands. Water is plentiful and constant from a large spring and creek.

With the raw material at the furnace for the figures above stated, the cost of making iron would be about $14 25 per ton, and should not be more, as the estimates are full.

Charcoal, per ton of iron	$7 00
Ore, two and one fourth tons	2 50
Limestone, two thirds ton	50
Labor and incidentals	3 00
	$13 00
Add ten per cent. for any loss	1 30
	$14 30
Add two dollars, freight to Louisville	2 00
Total	$16 30

And we have a warm-blast charcoal iron of the best quality—equal in all respects to irons selling at Louisville now for twenty-three dollars, No. 1, and eighteen dollars "Mill" grades. Supposing the furnace to make half of No. 1 and half "Mill," the average would be twenty dollars and a half, which would leave a handsome profit.

The iron would have about the following composition, this being an analysis of Trigg iron:

Iron	94.71	per cent.
Carbon	2.87	"
Silicon	1.93	"
Phosphorus	0.18	"
Sulphur	trace.	

CENTRE FURNACE.

Returning to the rolling mill, and crossing the Cumberland, we find Centre Furnace, two miles off to the west, in Lyon county. The site of the old Fulton Furnace is near by.

Centre is also a large charcoal furnace, with modern improvements—a large stack, in good condition, good out-

buildings, steam hoist, horizontal blowing engines, etc. The surrounding hills are full of ore, and several mines have been worked quite close to the furnace.

The ore is of the same general character as that in Trigg and Caldwell counties, is mined in the same way, just as cheaply, and yields as well in the furnace. Analysis shows it to be as pure, the following being an average sample taken from one of the mines:

Iron oxide	71.13
Alumina	2.29
Lime	2.61
Magnesia	1.48
Water	10.89
Silica	11.26
Total	99.66
Metallic iron	49.80
Phosphorus	0.092

This furnace is also surrounded by good charcoal timber; water is abundant, and limestone of good quality quite near. The cost of making iron would then be about the same as at Trigg Furnace.

The iron from these furnaces has been used to make the boiler-plate so well known on the steamboats in our Western rivers, and which has gained so general a reputation for excellent quality and uniformity. The process, however, is the most expensive used in iron working, and hence the mill has not kept in full blast during the past year or so. The pig iron is treated in small charcoal knobbling fires—that is, it is made into wrought iron by puddling in charcoal. The charcoal blooms or balls are shingled, rough rolled, cut and piled, then heated and rolled. The bars are cut and piled for plates, heated and rolled to plates of different sizes and thickness. The rolling mill is quite extensive, consisting of large rolling mill building, out-houses, machine shops, etc., knobbling furnaces or fires, refinery, hammers, shears, etc.

The plate trains are, for large plate 26-inch, and for small plate 18-inch, well arranged and adapted for the work. By the process of "knobbling or sinking" the 0.18 per cent. of phosphorus is reduced to 0.03 per cent., which, to a great extent, accounts for the excellence of the plate, and its great strength. Having shown what the ore is capable of in making charcoal iron and wrought iron from it, I will refer to the question of making a cheap iron suitable for steel, using coke as fuel in the blast furnace.

COKE IRON.

The fact has already been mentioned that the coal field of Western Kentucky extends to within a very few miles of these ores, and that the coal, which is of excellent quality for iron smelting, occurs in veins five feet in thickness.

The E. & P. Road cuts through this coal field, and already the line of the road is dotted with numerous coal mines, which furnish coal to Louisville at a price lower than Pittsburgh can send it. Coke ovens have already been erected, and the coke has a good reputation with iron men.

Along this road are many points which would be excellent furnace sites. There is Rockport, where the road crosses the Green, a river navigable at all seasons, and Nortonville, the crossing of the E. & P. and St. Louis and S. E., and many other places in the coal field; or, if one preferred taking coal to the ore, there are favorable locations in the ore region. Either way the distance need not exceed thirty or forty miles, and could be put at much less.

Coal can be mined very cheaply, and two tons coke should not cost over $2 75 at the mines; if freight for thirty miles were added, it would not be over $3 50. The ore can be mined for one dollar—say $2 50 for two and one fourth tons—freight on two and one fourth tons thirty miles would make it, with the loading and unloading, about $3 50. Then the cost per ton of iron would be—

	At the coal.	At the ore.
Coke, two tons	$2 75	$3 50
Ore, two and one fourth tons	3 50	2 50
Limestone, three fourths ton	60	60
Labor and incidentals	3 00	3 00
Total cost	$9 85	$9 60
Freight to Louisville	1 50	1 75
	$11 35	$11 35
Add ten per cent. on total cost	96	98
Cost at Louisville	$12 31	$12 33

These estimates are for a grade of iron from which steel for rails or merchant bar or "shapes" could be made at a low figure. Any concern which could buy such iron at Louisville for sixteen dollars would not need to fear failure in steel-making.

GEOLOGICAL SURVEY OF KENTUCKY.

N. S. SHALER, Director.

IRON:

THE

IMPURITIES WHICH COMMONLY OCCUR WITH IT,

AND THEIR EFFECTS.

BY WM. B. CALDWELL, Jr.

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IRON—THE IMPURITIES WHICH COMMONLY OCCUR WITH IT, AND THEIR EFFECTS.

Careful study of the physical character of the metals, and of their chemical composition, has brought out so many points hitherto considered mysterious, that we now have a term, "chemico-physical," to designate this important combination, and investigations are now universally conducted on this basis.

The limits of this work are necessarily narrow; but the object is to collect a few facts in regard to the iron industry, which may be of use to those producing or working iron.

This can be more easily done, since it is now common in iron districts and among iron workers to hear terms constantly used which were, a short time since, familiar only to chemists; for the reader will more readily follow the discussion if accustomed to the terms, such as silicon, phosphorus, sulphur, manganese, etc.

Iron is no longer made or worked at hap-hazard, but is treated as it should be, I will not say scientifically, but with common sense. The manufacturer and merchant are no longer guided entirely by the appearance of the fracture in valuing iron, but frequently depend on chemical analysis alone.

The iron industry is now in far better condition than it has been for years; and yet we have not, and probably never will reach, the high prices of 1872; but with that economy and perfection of method of manufacture necessary in every business, success is not now, as it was two years ago, uncertain and improbable.

Aside from the close and minute economy necessary everywhere, a comprehensive and accurate knowledge of ores, fuels, fluxes, etc., is required, and also the manner of using this knowledge to produce the best results; for of what use is information concerning the chemical composition of the materials, without the ability to make practical use of the analysis?

Chemists are now indispensable at all enterprising works, and becoming more necessary and useful as others learn to apply the results of their investigations.

Before entering fully upon the subject, a short discussion of iron will not be out of place.

When pure, iron is exceedingly soft; has a bright, somewhat silvery color, and melts only at very high temperatures; but the difficulty of preparing it absolutely pure is so great, that specimens are very rare. Iron does not normally occur in the metallic state on the earth; but meteoric masses of iron are often found, and also specks of metallic iron in lavas; the latter, however, may, in some cases, be proven to be terrestrial.

The usual mode of occurrence of iron is in combination with oxygen, and in this form, united with other substances, it is found almost universally distributed throughout the mineral kingdom.

When the amount of iron in any substance is sufficiently large for the economical production of the metal on a commercial scale, and the metal so produced is free from an excess of impurities, such a substance is called an "Iron Ore." There is, however, a point which cannot be too distinctly and emphatically stated, which is, that iron is an elementary substance, and as such is always the same, whether free or combined, whether produced from an ore or some combination unworkable on account of impurities; that is, the metal iron, when freed from its combination with other substances, is invariably the same, no matter what combination it was taken from. This is of course self-evident to the chemist; but many practical men of great experience still imagine that the ore has an influence beyond the mere question of the impurities which it gives to the metal. Such impurities are dependent not only on what the ore contains, but also on the physical structure of the ore; for two ores of

the same percentage of impurities, but of different density and infusibility, treated in the same way, will give very different results.

In combination with other substances, of course the metallic properties of iron are lost, when the greater part of the mass is not iron; but by the operation of the blast furnace the foreign substances are removed, and pass off as slag, leaving the metal, which is then called cast iron or pig iron. The metal thus freed from the slag is not pure; for in order to melt and run out of the furnace it must contain carbon, and it also takes up silicon, etc.

Metallurgists are striving to establish a new classification of iron and steel; but, according to the commercial classification, which is still used, we have: cast iron, wrought iron, and steel, differing in consequence of, and in proportion to, the amount of carbon present; and these three classes, subdivided again, according to appearance of fracture, giving—

UNDER CAST IRON—Gray, mottled, and white.

UNDER WROUGHT—Fibrous and granular.

UNDER STEEL—"Soft" and "hard;" but the varieties under this head are very numerous.

Here, however, it is necessary to say again that the iron, which forms the basis of all these varieties, is always the same, and that these differences are owing to a difference in chemical composition alone, or to a combination of chemical composition and molecular structure.

As a general rule, it may be said that the varying element in these classes, and the one causing, to a great extent, so much difference in them, is carbon, of which cast iron contains most, steel less, wrought iron least; but, merging, as they must, into each other, the boundary lines are very indistinct, more especially as other substances, as silicon, phosphorus, sulphur, etc., modify the influence of carbon. It is this influence of numerous substances which renders it impossible to say what the effect of any one would be without knowing the composition of the metal.

It will be well to discuss briefly silicon, sulphur, phosphorus, etc., and the effect of each separately, then the combined effect of some important and common impurities.

SILICON.

This is one of the most important of all the substances, elementary or compound, which comes under the notice of the iron-master, as it is always present in iron and steel in varying amounts, and exercises great influence on the character of the metal. Not only is it important as silicon, but also as silicic acid—silica or quartz—in which last named form it unites with oxides, and produces slag or cinder, without which the metal could not be produced or worked. The slag covers the metal and protects it from oxidation in the furnace; also carrying off the impurities which would be injurious to the iron; and then the principal process of metallurgy—the carrying of oxygen from the air to the impurities in the metal—is effected by the slag. We speak of burning out silicon, carbon, etc.; but it is done by means of the slag, which takes up the oxygen and gives it up to the impurities.

Too much stress can scarcely be laid on the character of slags in metallurgical processes.

In the reduction of iron ore, not only is oxygen taken from the iron oxide, leaving metallic iron, but also from silicic acid, leaving silicon; and this silicon has a great affinity for iron, with which it unites. It would seem, however, from the observations of Dr. J. Lawrence Smith and others, that silicon exists also in iron in the free state, probably graphitic. Although silicon has a great affinity for iron, it would appear that the presence of carbon is necessary for the production of iron silicide, as all attempts to produce it without carbon have failed.

The blast furnace is favorable to the production of highly carbonized and also very silicious metal, as there is a highly carbonized reducing atmosphere at a very high temperature,

acting on iron ore, silicic acid, lime, etc. The iron oxide in the ore loses oxygen, and metallic iron being set free, takes up carbon and silicon, the percentage taken being dependent largely on the working of the furnace, as temperature, force of blast, amount of flux, fuel, etc.

In general it may be stated, that a high temperature produces silicious iron, and merely heating the air blown into a furnace will raise the amount of silicon from one per cent. often to from two to three per cent.

The action of silicon, and the form in which it exists in iron, are but little understood, and yet we may undoubtedly say that silicon renders iron harder and more brittle; but it is still doubtful whether it may not be an advantage to steel when present in very small quantities.

In cast iron, the amount of silicon is usually from one to three per cent., but often as high as six, in which case the metal is hard, and is called silver gray. Silicon in very small quantity is believed by many to ruin steel and wrought iron; but up to three per cent. does not injure cast iron, for the soft, easily worked, No. 1 Foundry iron usually contains about this percentage. For purposes where a hardened or chilled surface is required, however, silicon is very prejudicial when the percentage exceeds about one per cent. (See page 16, chilled castings.)

PHOSPHORUS.

For many years this substance has been the great trouble of iron workers, and the attempts to eliminate it economically have been as persistent and fruitless as the search for the philosopher's stone. To-day the iron industry is at a point where great and important changes will necessarily soon be brought about. Districts which abound in iron, heretofore branded with the stigma "high phosphorus," will now come to the front with their cheap iron, and produce steels of the finest quality, free from phosphorus. The whole world is working at it, and, thanks to the freedom with which men of science give their experiments to the public, the workers are all informed as to what has been done, and all are working in the same direction, viz: towards the removal of phosphorus, in the form of phosphoric acid, by means of highly basic slags. Success in this effort is almost a certainty; and it will give an impetus to the iron industry which will be of the utmost importance, especially to the Southern States, since it will settle at once the question of their power to make steel.

The effect of phosphorus on iron is very marked, and even small fractions of one per cent. are taken into consideration. It causes cast iron to melt very thin, and hence very fine, small castings are usually made of iron carrying several per cent. of this substance. In wrought iron, 0.30 per cent. produces some cold-shortness unless the iron has been well puddled, and the carbon brought down low. In steel, a difference of but few hundredths of one per cent., the carbon remaining constant, will make a marked difference in the toughness.

Phosphorus exists in iron in the form of phosphide; but it is impossible to say whether it is always the same one of the many phosphides of iron. At any rate, one tenth of one per cent. will ruin hard steel for many purposes, and this small percentage will be found equally distributed through the mass. Phosphorus seems to cause carbon to tend to separate out as graphite.

The refining process removes phosphorus, as the following experiments,* made on 1,000 pound charges, will show—

Pig iron containing 0.23 per cent. gave refined metal with	0.03 per cent.
Pig iron containing 0.90 per cent. gave refined metal with	0.20 per cent.
Pig iron containing 0.90 per cent. gave wrought iron with	0.027 per cent.
Pig iron containing 0.88 per cent. gave refined metal with	0.18 per cent.

SULPHUR.

This is also a very common impurity in iron, but is more easily kept out than phosphorus. The blast furnace is really the place to remove sulphur, which, when lime is plentifully used as flux, goes off in the slag as calcium sulphide. Sulphur tends to cause the production of white iron; acts against

*These experiments were made with the assistance of Mr. J. M. Duncan, Superintendent Roane Iron Works, Chattanooga; and, after many trials, we felt sure of the success of the operation of removing phosphorus from pig iron.

high carbon in cast iron; causes the metal to flow thick, and the castings to be rotten, the latter effect being produced by 0.5 per cent. and even less. In steel and wrought iron sulphur is very injurious, if present to the extent of one tenth of one per cent., producing in steel brittleness when hot, and cracking while being worked.

MANGANESE.

This metal is soft and ductile; but united with iron, tends to produce hardness, and also to raise the melting point. It is known in commerce in the form of "spiegel-eisen," which contains twenty per cent. of the metal, and as ferro-manganese, which may contain as much as seventy-five per cent. thereof. The manganese present in cast iron, when as much as ten per cent., has the peculiar property of causing carbon to be all combined, and also of raising the percentage of carbon up to five per cent. Manganese is now added to steel to counteract the effect of phosphorus, which it does, however, only to a certain extent; for both harden steel, and much manganese is injurious.

COPPER.

This is an impurity but rarely found in iron and steel; but it is stated to produce rottenness or red-shortness; to diminish carbon, and injure iron very much as sulphur does, but may be present, without injury to the metal, in larger quantity than sulphur. I have seen very fair iron with 0.3 per cent., and at Harrisburg steel of very good quality has been made (I have been told) with as much as 0.5 per cent. copper.

ARSENIC.

We need scarcely expect to find arsenic in iron and steel as a rule; but it occurs sometimes, and produces hardness and brittleness. If present in any quantity, it is likely to be detected when the metal is tested for phosphorus, as it also produces, with molybdic acid solution, a yellow salt.

CARBON.

All of the inorganic modifications of carbon, excepting the diamond, are important in the metallurgy of iron. The forms of carbon most common and important are: coal, and the product, coke; wood, and its product, charcoal; peat, graphite, amorphous carbon; many of the chemical compounds, as carbonic acid and carbonic oxide, carburetted hydrogens, etc.

Not only is carbon important on account of its use as fuel for reducing and working the metal, but also because of the great value which its presence gives to iron. As has been stated before, iron would be too soft, without carbon, for the innumerable uses to which we now adapt it by slightly changing the percentage of this element; and again, carbon used as fuel is the only means of producing the metal economically. The three great divisions of iron, mentioned before, viz: cast iron, wrought iron, and steel, vary distinctly in the amount of carbon, excepting that the line dividing them is not and cannot be sharply drawn.

Cast iron contains from 1.5 to 5 per cent. carbon. Steel contains from 0.25 to 1.5 per cent. carbon. Wrought iron contains up to about 0.25 per cent.

It will easily be understood that a statement of percentage of carbon cannot always decide at once to which of the classes a piece of metal would belong; for other substances affect greatly the influence of carbon, as, for instance, phosphorus, which renders steel very brittle, if the amount of carbon is great; and yet such a statement of amount of carbon does indicate at once what the metal is called, excepting at the boundary line between the classes.

It may very soon be decided by the metallurgists of the world whether the old classification shall hold, or a new manner of designating the varieties be chosen. Certainly it is now difficult to decide which is steel and which iron, according to the old manner of calling things, when it is a question as to "plate steel," containing 0.10 to 0.12 carbon, and iron plate with the same percentage.

Carbon hardens iron in proportion to the amount present in the combined state, and renders it more fusible, so that wrought iron is soft and very difficultly fusible, while white cast iron is hard, and melts more easily than steel, which also melts more easily than wrought iron.

The property of welding is also strongly affected by carbon, decreasing with the increase of carbon, as does also malleability. Wrought iron and steel are both distinctly malleable and ductile, while cast iron shows but faint traces even of malleability; and again, wrought iron welds perfectly, steel less perfectly, cast iron not at all.

There are two forms of carbon in iron, viz: "chemically combined" with the iron, and "mechanically mixed," as graphite, the graphite never occurring without the combined form, which, however, often occurs alone, as in white cast iron, steel, and wrought iron. This peculiarity of occurrence, in two forms, varies very materially the character of that class of iron in which it exists, viz: cast iron, producing what are called the different "grades." It is true that graphite is sometimes found in high steel when cast in large masses, or when even small masses are cooled very slowly; but, as a rule, the carbon in steel is all chemically combined, as it is also in wrought iron. (See page 13.) It will be as well now to discuss under "*Cast Iron*" the manner of occurrence and behavior of carbon in its two forms. The common name for this kind of iron is "pig" iron, which is the first product from the ores, the most impure of the three classes of iron, and the one from which the others are made. It contains, roughly stated—

93 to 95 per cent. metallic iron;
2 to 3 per cent. carbon;
1 to 3 per cent. silicon;

more or less slag, sulphur, phosphorus, etc. Carbon and silicon vary between greater limits, it is true, as in silver gray, silicon often going as high as seven per cent., and in white iron carbon reaching five per cent., the amounts depending largely on the character of ore and manner of working the furnace, but more especially the latter, which causes the production of the "grades" of iron called gray, mottled, and white.

GRAY IRON,

also called "Foundry Iron," is the typical "Cast Iron." It is a combination of iron with silicon, carbon, etc., in about the following proportions, taking No. 1 Foundry iron (coke) of good quality:

Carbon	3.00 per cent.
Silicon	2.75 to 3.00 per cent.
Iron	93.00 per cent.
Slag, etc.	1.00 per cent.

The carbon is partly "combined" and partly graphitic, the latter largely predominating, as a rule, in No. 1, and the two forms becoming more equally divided in the lower grades down to IV and "mottled," in which they are nearly equal; then, as the iron becomes white, the combined form predominates, graphite being absent in "white" iron, the "lowest" of the grades.

There is something peculiarly interesting in this division of the carbon, not only from a scientific stand-point, considering the chemical combination of a few hundredths or tenths of one per cent. of carbon with the iron, and the separation or crystallization out of the remainder in the form of graphite, but also in a practical view, as this behavior of the carbon very materially affects the character of the metal, as will be shown further on.

The cause of this division, or two forms of carbon, is easily understood and explained on the supposition that molten iron absorbs a large quantity of carbon, say 3.00 per cent., and, on cooling slowly, the greater part of this crystallizes out. On this assumption the carbon is all combined, or partly combined and partly amorphous, in the molten metal; most probably it is all combined; for sudden cooling will, in some cases, give a metal showing only combined carbon.

It has long been a favorite theory with many eminent metallurgists, that the condition of the carbon in iron is greatly influenced by the temperature to which it has been subjected

previous to casting, they claiming that white iron will be changed to gray if melted and heated to a point considerably above melting. In this theory the mysterious influence is "superheating," and the temperature at the time of casting is not considered.

It seems to me, however, unnecessary to seek some unaccountable agency to explain the fact that the same iron may be gray or white, according to the manner of casting, when we have the plain and simple reason that sudden cooling prevents the separation of graphite. The question of heating far beyond the melting point, producing gray iron, is, to my mind, merely a question of giving such a heat that the iron is not ready to chill immediately on touching the mold, and therefore the temperature at the time of casting is important, while any previous overheating can have no effect. This same theory is even carried into the blast furnace practice, with the statement that high temperature there produces graphitic iron by some peculiar effect of heat on the carbon; a very unnecessary hypothesis, since we know that high temperature gives highly silicious metal, and that silicon causes graphite to separate. (See page 12.)

Gray iron is a mixture of steel and graphite, the steel being a sponge or network inclosing the graphite, and this explains the character of gray iron and the difference between gray, mottled, and white, for we may consider gray iron as a low steel, inclosing graphite; mottled iron a higher steel, inclosing less graphite; white iron a very high steel, with no graphite. Now, as before mentioned, in proportion to the carbon combined with iron, it is more fusible, more brittle, and harder; and we know that gray iron is less easily melted, is softer and tougher than either mottled or white. These properties render it especially suited for castings, because when cast it is soft enough to be worked easily with cutting tools, being also stronger than the other grades. Another peculiarity of gray iron is, that when it cools down to the point of hardening, it sets suddenly, and slightly expands, thus filling the mold well.

MOTTLED IRON

is so called from the appearance of its fracture, which shows gray specks in a white ground. It contains usually less silicon than gray iron, and also less carbon, the combined and graphitic being about equal in true mottled.

Owing to a larger percentage of combined carbon, mottled iron is harder, more fusible, and more brittle than gray, and shrinks instead of expanding when cast. It has a peculiar property of passing through a pasty condition when melting, which adapts it especially for puddling; otherwise very little use could be made of it.

This iron is made at lower temperatures than gray iron, and is less impregnated, therefore, with those substances which enter by reduction; but it always contains more sulphur, because the furnace, being much colder, the pyrites of the coke is not decomposed high up in the furnace, and because it is not possible to carry a heavy burden of lime on a cold furnace, for fear of scaffolding. If the lime were in excess, it would carry off sulphur in the slag as sulphide of calcium; but this is still more true of

WHITE IRON,

which is usually the result of a colder furnace, and contains less silicon and carbon than either of the others, which carbon is all "combined," and more sulphur. In fact, sulphur tends to prevent iron absorbing much carbon, and also to the formation of white iron.

White iron may, however, be owing to the presence of manganese, in which case the carbon is high, usually five per cent., when manganese is as much as twenty per cent.

The hardness, brittleness, lack of strength, and contraction on cooling, render white iron unfit for castings; but, melting easily, and passing through a pasty condition, it is well adapted for puddling.

The more important discussion of the combined action of some of the impurities already mentioned brings up intricate questions; but there are some plain facts to be noted.

CARBON AND SILICON.

In cast iron these two substances occur in large quantities, usually nearly equal in gray iron, which contains about three per cent. of each. The reduction of silicon is greatest in the blast furnace when the temperature is high, and this is also favorable to a highly carbonized metal, and, as some metallurgists say, to the production of a graphitic metal; but I think it is clear that the separation of the graphite in the cast iron is not owing directly to a high temperature in the furnace. (See page 13.) It seems that silicon and carbon replace each other to a certain extent; but a high percentage of silicon generally occurs with a high percentage of carbon, and on cooling, this carbon separates out as graphite, in proportion to silicon percentage, so that very silicious metal, as silver gray, contains almost exclusively graphitic carbon.

Why silicon causes graphite to separate, is the unsettled question. It is a question which has not received the attention which it merits; and with this fact, so evident to any one who is at all acquainted with metallurgy, that high silicon and combined carbon do not occur together, there can scarcely be a question as to the action of silicon in the case. Why silicon has this effect is not easily determined; whether the separation of graphite is owing to a mere replacement of combined carbon by silicon, or to the mere presence of silicon, which acts then in some unaccountable manner, or to silicon affecting the melting point, and by keeping the metal fluid, melted sufficiently for the purpose, at a low temperature, allowing time for separation of carbon, or lastly, and very probably, to the action of silicon, preventing a sudden contraction at the moment of solidification. This fact of sudden contraction, whether by cooling or by shock, is of great importance, and exerts a powerful influence on the form of carbon. (See page 21, on difference between hammering and rolling steel.)

However the question may be settled by future investigation in regard to the reason of this peculiar action of silicon, the fact remains, and I think it can be safely stated—

1st. That silicon, to the amount of three per cent., will cause iron to be gray and highly graphitic.

2d. That without materially lowering carbon, if silicon be lowered to one per cent. in such an iron, it will give white iron by chilling.

3d. That any iron containing less than one per cent. silicon will give white metal by sudden cooling, whether it be cold-blast charcoal iron or the commonest silver gray coke metal refined.

Pig iron (No. 1) containing silicon, 4.06; graphite, 2.98; combined carbon, 0.23; gave refined metal with silicon, 0.21, graphite trace; combined carbon, 2.45; and many experiments gave similar results.

These instances are sufficient to show that the use of cold-blast charcoal iron is not necessary to get a metal which will give a perfect chill, and surely lend additional weight to the other arguments in favor of the idea that silicon causes carbon to separate out as graphite.

This may seem, at first sight, of but little practical moment, and yet it is of the greatest importance to one of the large industries of the country, viz: car-wheel manufacture, and the manufacture of chilled castings generally, besides the importance it has for "rolls," etc.

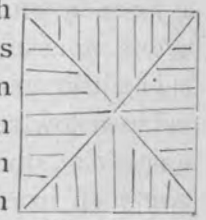
For car-wheels, an iron is necessary that will give a hard surface when cast against iron, and a soft, strong body where cast against sand. For this, a metal containing about one per cent. of silicon is necessary, and that is just about what we find in the high-priced cold-blast irons. Now, by refining them, the commonest, cheapest irons will answer the purpose. This is the subject of a patent taken out lately in this country, but has been in use for many years in Germany, where they refine for "rolls," and chill castings, as at Königshütte, in Silesia, where I saw, five years ago, the operation constantly conducted of refining eight tons at a heat in about eight hours.

In this connection, there has been much discussion as to the cause and peculiarity of this property, which some irons possess, of giving a hard, white surface, or "chill," when cast

against iron. Among other reasons assigned, a third form of carbon has been said to be the cause; but this third form of carbon has been found in this quality of iron (as it seems to me) merely because combined carbon was high. Treatment of carbon residue, from solution of iron in hydrochloric or dilute nitric acid, and finding a substance which burns or volatilizes below redness, does not prove the existence of a third form of carbon. Carbon may be deposited in an amorphous form when iron containing only combined carbon is dissolved in acid, and the more dilute the acid, and the slower the action, the more of this amorphous carbon will be left; so that solution in dilute hydrochloric acid, with the aid of a galvanic current, is even used by no less an authority than Professor Bunsen, to obtain the carbon from iron, which carbon is then burned and CO_2 weighed. A stronger acid would evolve more hydrogen, which, in its nascent state, would tend to carry off carbon as carburetted hydrogen; but it rarely happens that simple solution in acid removes all of the combined carbon; and of course the greater the quantity of combined carbon in the iron, the greater the amount of amorphous carbon left. Again, even in the mild steels, with only 0.12 carbon, it is well known that, in making color tests, the nitric acid used (1.22 sp. gr.) rapidly dissolves the steel, but leaves a floculent carbon residue, which must be dissolved by longer standing at 80° C. This residue is combined carbon, left when the acid dissolved the metal; and if the steel is very high, say 1.5 per cent. carbon, this residue, on one decigramme, will be very considerable; but it will be entirely dissolved by two to three hours standing at 80° C.

Now, chilled iron is really a very high steel; and, it seems to me, that in order to establish the theory that "chilling" is due to this third form of carbon, it must be present in any combination of iron and carbon which will perceptibly harden by sudden cooling; for steels as well as cast irons contain graphite and combined carbon, provided the cooling be very slow.

Chilling is not at all strange in itself; but it is as yet a mystery why silicon prevents it. The hardening or crystallization takes place in the most natural manner; in a plane perpendicular to the plane of the surface which chills or cools, just as any crystallization shoots out in a plane perpendicular to the surface from which it begins. If we cast from a chilling iron or high steel an inch square bar, in an iron mold, the planes of crystallization will run in to the centre, forming distinct diagonal lines. The bar will be smaller than the mold, showing that there has been considerable contraction; the metal will be intensely hard, and the carbon all combined.



WROUGHT IRON.

The impurities are much less in this form of iron than in cast iron. It is made from cast iron, and the process, called puddling, removes silicon, and reduces carbon down to about 0.2 per cent., lowering also the percentage of phosphorus and sulphur.

Being made by squeezing together small particles of iron, of course the mass is never homogeneous, and when rolled out, consists of bundles of fibres, separated by films of slag. But there are two kinds of wrought iron known in commerce, "fibrous" and "granular," the former being the truer "wrought iron," and the latter approaching steel, the difference in carbon being that the fibrous contains less than the granular. The fracture may, however, give false indication of the nature of the metal, for a good smith can bend a granular iron so as to show some fibre, or break a fibrous iron so as to appear granular. In fact, the quality of the blacksmith often has as much to do with the working of an iron as its quality; but he cannot make the iron strong after it is worked.

Bad iron is the result of one or several of many possible causes. The purest iron may be spoiled by burning or overheating, although such pure iron will stand more heat than

impure irons. This "burning" is, in my opinion, not only removal of carbon, but oxidation of the metal; for if it were merely removal of carbon, the iron would be softer instead of more brittle. There is also a change of molecular structure, of course.

The iron "pile" or "packet" is put into a heating furnace and soon oxidizes sufficiently to be covered with a scale. This scale, or oxide of iron, gives up part of its oxygen to carbon, taking up oxygen again from the air, and the carbon thus oxidized passes off as gas; but at the same time it is undoubtedly true that, at this intense heat, oxygen also goes to the metal, and, gradually passing in, soon renders the most porous parts of the mass brittle by forming oxide of iron, which is disseminated through the mass. Therefore, the less dense the metal the more readily "burned."

There are two kinds of brittleness in iron, the one called "cold-shortness," or brittleness when cold, and the other "red-shortness," or brittleness when hot. As a rule the two do not occur in the same metal, but if the red-shortness be caused by burning, or by bad puddling, leaving the iron green or badly balled, the result will be an iron both red and cold-short. Red-shortness is generally caused by sulphur, of which but a few hundredths of one per cent. will cause cracking in the rolls; but, on cooling, this brittleness will not exist.

Cold-shortness is generally owing to phosphorus, which may be as much as half of one per cent. without greatly injuring the iron, provided it has been well puddled, so as to make the carbon low. Such an iron will work smooth and well in the rolls, but will be somewhat brittle when cold, and this brittleness will be greater the higher the carbon. A theory generally held by iron-masters has been, that a mixture of red and cold-short iron would give a strong neutral metal; but only in so far as dilution affects it is the theory true. Five hundred pounds each of two irons, the one containing one half per cent. phosphorus, and the other three tenths per cent. sulphur, will give a metal with a quarter per cent. phosphorus and fifteen hundredths per cent. sulphur. Puddling will still further purify it, and the result will be a good iron. But phosphorus and sulphur do not neutralize each other.

The purification of iron by puddling should be more closely considered than it is at present; for, by properly conducted and careful work, it is possible to remove sixty per cent. at least of the phosphorus and sulphur. For this result the iron should be "bled"—that is, the slag run off before "balling." That iron may be still further purified by puddling is undoubtedly true; for, in some experiments made with Mr. J. M. Duncan, of the Roane Iron Company, Chattanooga, we puddled a heat of 1,000 pounds of an iron with 0.90 per cent. phosphorus, and produced muck bar with 0.03 per cent. This would, however, scarcely be economical puddling for ordinary work, and yet, for boiler plate, it would be far cheaper than "sinking" with charcoal.

STEEL.

Under this heading it will be necessary to be brief, although the subject would admit of extensive treatment in detail; but our State is as yet without steel industries.

As has been said before, it is difficult to say what steel is, for it is now made lower in carbon than even good wrought iron, or containing almost as much carbon as cast iron. Owing to its crystalline structure, steel bears less percentage of impurities than iron can safely carry, *i. e.*, leaving carbon out of the question. By impurities, then, we mean phosphorus and sulphur, and the amounts of these which may be present depend largely on percentage of carbon, and also on the use to which steel is to be put. Phosphorus in small quantity, say one quarter of one per cent., does not prevent steel working well, provided the carbon be low; but when cold, such steel is decidedly brittle, unless carbon be at least as low as 0.25 per cent., and manganese should be up to 0.60 per cent. Manganese acts in more than one way advantageously to steel. It prevents, to a great extent, boiling and blowholes, by its tendency to check the oxidation of carbon during casting and while the metal is setting in the molds; it

also renders less active the oxidizing tendency of the heating furnace, which would cause red-shortness; and although manganese itself renders steel harder and more brittle, it neutralizes, to a certain extent, the cold-short action of phosphorus.

In working steel with 0.30 per cent. phosphorus, 0.25 per cent. carbon, 0.80 per cent. manganese, 0.03 to 0.05 per cent. sulphur, I have found that it was soft, and gave excellent results under a steam hammer or on the anvil, cold bars one inch square bending completely over on themselves and sustaining repeated blows from a sledge; but the same worked hard in the blooming rolls and one ton ingots, cracked badly. Those ingots which rolled well gave bars which were broken by a six hundred-pound drop falling six feet on four-foot bearing. Lowering phosphorus to 0.20 and manganese to 0.50 gave steel which worked soft, and stood repeated blows from a fifteen hundred-pound drop falling nine feet. In the former steel graphite was always perceptibly present, while in the latter it was rare, and then only in minute quantity. There is a remarkable difference beween the action of the hammer and the rolls on steel, more especially when carbon is high. The hammer exerts an influence similar to the cooling action of a chilling surface, producing sudden contraction, and this causes carbon to remain in the combined form, while the rolls are slower in their action, and graphite tends to separate out.

GEOLOGICAL SURVEY OF KENTUCKY.

N. S. SHALER, DIRECTOR.

REPORT

ON A

BELT OF KENTUCKY TIMBERS,

EXTENDING EAST AND WEST ALONG THE SOUTH-CENTRAL PART OF THE STATE,

FROM COLUMBUS TO POUND GAP.

BY LAFAYETTE H. DEFRIESE.

PART X. VOL. V. SECOND SERIES.

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INTRODUCTORY LETTER.

NEW YORK, February, 1879.

Professor N. S. SHALER, *Director Kentucky Geological Survey:*

DEAR SIR: I herewith submit a report upon a belt of Kentucky timbers, extending from Columbus, on the Mississippi river, to Pound Gap, on the Virginia line.

The data for the report were obtained on a trip made for that purpose during the summer of 1878. The general plan of the report does not differ materially from that of previous reports; but the great extent of country covered by it, and the particular objects in view in this report, rendered necessary considerable differences in detail. Such of these as are important will appear from the body of the report.

Very respectfully,

LAFAYETTE H. DEFRIESE.

REPORT ON A BELT OF KENTUCKY TIMBERS, EXTENDING IRREGULARLY EAST AND WEST ALONG THE SOUTH-CENTRAL PART OF THE STATE, FROM COLUMBUS TO POUND GAP.

PRELIMINARY REMARKS.

In each of the several previous reports made on Kentucky timbers, attention has been called to a comparatively limited portion of country; and all the conditions of timber growth, the relative numbers of the different kinds of timbers, the changes that these several kinds of timbers undergo under certain circumstances of time or position, have been inquired into somewhat minutely, and in a detailed manner. Such previous reports have been occupied, therefore, each in its own locality, with minute examinations and discussions of tree life, growth and changes, and there has not been much effort to direct attention to the similarities and dissimilarities shown to exist, by comparison of reports, on widely separated localities. In other words, each previous report has been detailed in character and limited in locality. This report is intended to be exactly the reverse. It deals with a very wide extent of country, and in a more or less general way. Its principal objects are to embrace under one view timber growths existing under the most widely different conditions possible within the State, and to call attention to any marked changes that may be found to accompany such differences of condition, and especially to discuss the effects of height above drainage upon such growths. A better opportunity for the latter purpose could not be had than presents itself to one who passes from the swamps and hilly, rolling country of Western Kentucky onto the level and fertile Blue-grass Region of the central part of the State, and thence across the high mountains, deep valleys, and wild ravines of the eastern portion. Almost every variety of topographical and geological condition to be found in the State is met with on this journey, and the corresponding effects of such changes upon forest growths can be seen and studied.

It should be borne in mind, however, in reading this report, that my observations were confined to a very narrow belt on either side of the line of travel; and that, while I brought to my assistance facts obtained from elaborate and minute study in various parts of the State, nevertheless I may have erred at times from having been necessarily confined to so narrow a strip of country. Conditions may exist at one point which are exceptional rather than general, and which, a few miles distant, would cease to exist altogether. Erroneous reasonings may thus arise, which could not be avoided under the circumstances; though, in preparing data, great care has been taken to avoid material error.

Another source of possible error in such a report as this, to which attention should be called at the outset, arises in dealing with comparative heights above drainage. In a rapid trip over so great an extent of country it is impossible to keep a stationary barometer to correct the fluctuations of the instruments carried; so that, in many instances, heights had to be more or less estimated. Such a source of error was unfortunate; for a difference of level of a few feet will often make a material difference in the growth of timbers, and interfere with comparative work.

GENERAL REMARKS.

In passing from the extreme southwestern to the extreme southeastern part of Kentucky, almost a complete change in forest growth will be noted. This singular change—a great part of which I cannot account for at all at present—begins first to be noticed, along the belt covered by this report, in Madison county, in that cluster of hills of which "Big Hill" is the centre and the most conspicuous. An exception to

this statement should be made in the case of linden or basswood trees, a few of which skirt Muldraugh's Hill farther to the west. (By Muldraugh's Hill, is here meant the entire range of hills bordering the Bluegrass Region on the south.) About the vicinity of Big Hill the first pines (*P. mitis*) make their appearance. Not a single coniferous tree or bush, with the exception of the swamp cypress and a few small cedars in Northwestern Kentucky, is to be seen in the entire western part of the State.

The pines first appear on the dry Waverly shales, extending down to the foot-hills along the knobs about Big Hill, and are also found on the Conglomerate, capping the tops of the highest knobs in this region. Their entire absence in Western Kentucky, and their presence in Eastern Kentucky, cannot be due to difference of geological formation, for both Waverly and Conglomerate are found in the western part of the State. Nor can it be due merely to the height of the hills and mountains in Eastern Kentucky; for pines are often found here on hills much lower than many in Western Kentucky. In another place, and under its proper head, I shall give what I conceive to be the reason of this peculiar phenomenon in the growth and distribution of the pine in Kentucky. At present, I wish merely to call attention to the marked difference between the forest growths of the western and those of the eastern part of the State.

In passing from the west to the east, the first hemlock trees (*Abies Canadensis*) were found by Professor Shaler in a Devonian shale ravine, about five miles north of Irvine, in Estill county. In a previous report on the timbers of the North Cumberland (Bell and Harlan counties), I called attention to the fact that, in that part of the State, hemlock appeared only on coal-measure formations, and was confined almost entirely to the Conglomerate. The finding of hemlock on Devonian shale, in Estill county, shows that in Kentucky, as in other States, that tree is not confined to particular formations. It should be said, however, that very little hemlock was found on this journey elsewhere than on coal-measures.

The magnolias are likewise first met with not far from Irvine, and between that place and Beattyville, while the American laurels (Rhododendron and Kalmia) are not found until the rockier mountains and wilder ravines farther east and south are reached. The same may also be said of the Amelanchiers and some other smaller shrubs. Thus, within comparatively few miles, and without any *apparent* topographical or geological reason for it, the whole character of the forest growth changes; and while the oaks and hickories of the west remain, there are added to them lindens, pines, laurels, and magnolias—stately and beautiful trees of the east alone. I say, without any *apparent* topographical reason, because these timbers are found alike on the mountains and in the valleys of Eastern Kentucky, while in Western Kentucky they do not appear, even on the highest hills. The same geological conditions can be found in the western part of the State as those on which these timbers grow in the east; so that the only point of difference which suggests itself, is in the higher mountains and hills of the east. It may be, therefore, with some of these timbers, that a wild and mountainous country is a necessary condition precedent to their introduction, and that their subsequent spread over the lower hills and valleys is a matter of course; but this is a subject which would require a great deal of preliminary investigation, before an opinion upon it could be safely hazarded.

Nothing is more certain to attract the attention of students of forestry in Kentucky, than the contrast met with in passing from the splendid woodlands of Muldraugh's Hill onto the Cincinnati limestone of the Bluegrass Region, near Danville. Especially is this contrast striking in Garrard county, which, though one of the finest and richest in the State, is nevertheless, with the exception of a few fenced-up groves, a treeless waste, devoid alike of water and forests. Coursing across it here and there can still be traced the dried-up beds of numerous streams, in which, within the memory of citizens living along them, water continuously flowed. Inasmuch as the Cincinnati limestone is an exceedingly waterless formation, or one

the surface of which is not adapted to the holding and flowing of water, I should have been in doubt whether to attribute the dry character of the country to the destruction of the timber or to the formation, had I not been told that water once flowed the year round through the now parched stream-beds. All that can be said is, that the people owe their present dearth to their past thoughtlessness; and the reckless destruction of forests now going on throughout the State portends an even greater calamity before there is a turn for the better. An able investigator of this subject well says: "Since 1835, the forest area of the western hemisphere has decreased at the yearly average rate of 7,600,000 acres, or about 11,000 square miles, and this rate in the United States alone has advanced from 1,600 square miles in 1835 to 7,000 in 1855, and 8,400 in 1876, while the last two years have been scarcely less exhaustive. Statistics for eighty years previous to 1835 show that we have been wasting the supply of moisture to American soil at the average rate of seven per cent. for each quarter of a century during the last one hundred and twenty-five years, and that we are now approaching the limit beyond which any further decrease will materially influence the climate of the entire continent. Many eastern regions, such as Afghanistan, Persia, India, and Asia Minor, once possessed of a fine climate and abundant harvests, are now often scourged by pestilence and famine; and it is altogether probable that their misfortunes began with the disappearance of their native forests. It is quite likely that we shall suffer in climate, fertility, and health before a great while, if we continue to destroy our trees as recklessly as we have done, and it behooves us to be warned in time. * * * For one hundred and fifty years we have been felling the forest; for the next one hundred and fifty we should try to restore what we have taken away."

In previous reports attention has been called to the fact that certain timbers, especially white oaks, do not seem to return again to forests from which they have once been driven by such an agency as fire. It has also been mentioned, that the formations best adapted to the growth of chestnut timber are the Conglomerate and Chester sandstones. On soils from these formations chestnut is normally found in the greatest abundance, and growing to the greatest perfection. In passing from Western to Eastern Kentucky, my attention was therefore attracted to the fact that when the Big Clifty (Chester) sandstone first appeared, which was in the neighborhood of Hopkinsville and on Pilot Knob, no chestnut appeared with it. Moreover, the white oak and liriodendron, away from the streams, seemed scrubby and scarce. Otherwise the forest was normal, and I searched in vain for any clue to the absence of these timbers. I finally came to the conclusion that, long ago, the entire country through here, reaching probably as far west as the Cumberland river, had been laid waste by fires, and had been barrens similar to those still remaining in the Purchase, and further east in Barren and other counties.

Mr. Irvine Kennedy, who has lived in this part of Kentucky for sixty-eight years, and who now resides near Elkton, informed me that my conjecture was correct, and that he could remember when all these heavy forests were a uniform growth of young trees, with not an old tree standing, except on streams too large for fires to sweep through their swamps.

I was afterward informed that some chestnut groves exist not far from Elkton, though I did not see a tree. It is possible that they stand in a piece of woods for some reason protected from the ravages of fires. Without special investigation made for that purpose, it is impossible to arrive at anything near the extent of Kentucky forests which represent, not the original growths of the State, but a kind of second growth, sprung haphazard from the burial-place of the primeval forests.

In a previous report on the timbers of the Purchase District (see Report, volume V, this series), attention was called to the remarkable absence of chestnut from that part of Kentucky, although the formation is a mill-stone grit waste, on

which chestnut should be found. A closer examination of the timbers surrounding the present barrens of the Purchase shows that there is very little white oak among them, except along streams and on low grounds. My present opinion is —subject, of course, to correction upon closer study—that the high grounds of almost the entire Purchase, from Tennessee river on the east to the Mississippi on the west, have been swept by fires and denuded of their timbers, and that the only difference between the other forests of this part of Kentucky and the present barrens is one of age. Both are second growths, and in both cases the primitive forests have been swept away by long-continued fires. In this report I give my reasons for believing that in former times the barrens have extended east beyond the Cumberland river, at least as far as Hopkinsville, if not, with local exceptions, to the waters of Big Barren river, leaving the narrow strip between the Tennessee and Cumberland rivers alone unswept by fires. Big Barren river is *probably* the eastern limit, in this locality, of the ancient barrens, part of which are still to be seen along it. The location of the northern limit of these ancient barrens is worthy of special investigation, if the view here advanced be correct, for they have certainly never extended to the Ohio river. Further on in this report I have called attention to certain chestnuts, evidently dropped by passers-by, having sprung up in the Purchase, near Clark river, and died. In this connection, an interesting question presents itself, and that is, whether chestnut and white oak will grow again in a forest once *thoroughly* burnt out, even if planted. If not, it may be that the barrens were never burnt over so long as to kill the roots and seeds of existing timbers, but only long enough to destroy the chestnut, white oak, &c., which would not grow again on the burnt-over grounds. The whole subject is one of the deepest interest, and should be thoroughly investigated.

REMARKS ON SPECIAL LOCALITIES.

There are some peculiarities connected with timber growth in certain localities which are worthy of mention. For instance, speaking broadly and generally, timbers are far better on the north sides of hills than on the south sides. This is doubtless due to the north side of a hill being shadier and damper than the south side, which is exposed directly to the drying heat of the sun. There are some exceptions to the statement that the finest forests grow on the north side of the hill. When the hill is very high, the observation made in the report on the timbers of the North Cumberland, that white oak flourishes best on the south side of the hill, is true. It is also true, even to a greater extent, of pines. If the hill be *low*, the best white oak, as will be noticed further on, like other timbers except pine, grows on the north side; if it be high enough to affect much the temperature of the north side, the white oak is found on the *warm* side; and where white oak is found on the north side of a high hill, it is found right at the base, where it is sheltered, or right on *top*, where the sun reaches it. In the case of the pines, it may be that the method of their distribution, of which I shall speak further on, has something to do with their confinement largely to the southern slopes of hills; but that cannot fully account for the fact, and it must be that the pines of Kentucky are not hardy, and seek the southern sides of mountains for warmth and sunlight.

Again, it would be natural to suppose, inasmuch as there are several belts of distinct timbers on each large hill, each belt composed of those timbers adapted to its height above drainage, that the various species of timbers would shade off gradually in ascending a hill; for instance, that the best white oak would be found at the base of the hill, that that a little higher up would be not quite so good, and that the quality would gradually grow poorer, until the white oak ceased altogether. To my astonishment, this did not seem to be a rule. That is, in descending a hill, the very first trees of a particular species are often as fine as any others found on the hill, unless want of richness of soil prevented. The observation certainly holds good with the beeches, hemlocks, and other timbers with which moisture of soil is the controlling requisite

of growth. They remain of the finest quality till they cease altogether, and their line of growth often forms a sharp and well-defined band around the hill.

As would naturally be expected, the timbers characteristic of a mountain top are not found directly on top of the mountain, but a few feet below the top, on the brow. The reason is, that on the level top there is usually a considerable depth of detritus and decayed vegetable matter, more or less moist, which gives to the timbers somewhat the characteristics of lowland timbers.

SPECIAL TIMBERS.

Reference has already been made to the peculiar, and, in many respects, remarkable distribution of pines in Kentucky. They are not found further west, in the timber belt here spoken of, than the Big Hill region, in Madison and Garrard counties; and the same counties are almost the northern limit of pine growth likewise, though scattering ones may be found on Muldraugh's Hill, still farther north. The pines met with are principally of the *P. mitis* or yellow species, though considerable numbers of *P. rigida* or pitch pine, *P. strobus* or white pine, and *P. taeda* or loblolly pine, are also met with. The question presented by this pine growth is, why is it limited so absolutely and arbitrarily to the southeastern part of the State? Is the reason to be found in the geological formation of that part of the State, or in its topographical nature, or in some problem connected with the original appearance of the pines in the Kentucky forests? As I have already said, the reason cannot be a geological one, for the exact geological counterpart of this section of the State can be found in Western Kentucky, where there are absolutely no pines. The true cause must then be sought in the other two alternatives—topographical nature of the country and method of original appearance and distribution—and I think that these two causes supplemented each other in producing the present peculiarities of pine growth. In order to fully comprehend the matter, let these facts be kept in mind:

1. The pines of Kentucky (hemlock is excepted for the present, and will be spoken of later) require a very dry soil, and for this reason are confined to the rock ledges of the high mountain tops, or to the dry shales of the lower levels. For this reason *pines cannot be distributed by the carrying power of water*, as in that case the seeds would be deposited in low, wet places, where growth would not take place.

2. In a general way, pines gradually increase in numbers from where they are first met with on the north to the southern border of the State, and from where they are first met with in the west to the eastern part of the State. This statement is subject to some modification on account of variations in height of the hills in this part of Kentucky, to be explained presently.

3. Pines are distributed over slopes of hills and mountains facing south and southeast.

A little reflection will show that only one hypothesis will satisfactorily explain all these peculiar facts in relation to the present growth and distribution of the pine; and that is, that the pine forests of Kentucky were introduced at a comparatively late date, and spread, from the vast pine forest and mountain growths of North Carolina, to the south and southeast of this section. Inasmuch as they could not have been distributed by water, for the reason already given, we must look to the wind as the motor power in their distribution. I was informed by all the citizens questioned on the subject that the prevailing winds in Kentucky are *from* the south and west. Of course, it is apparent at once that the pine seeds are carried north from North Carolina by the prevailing southern winds, while the western winds are almost a perfect barrier to confine them to the eastern part of the State. The trees work westward very slowly against the prevailing winds; and when the wind does blow from the east, it is liable to be accompanied by rain, which would destroy its power to carry the seeds to any great distance. If the pine seeds were carried by the winds from the south, of course they would be lodged on the south sides of the hills and mountains, and the pines

would naturally be first found there. I do not say that this is the *reason* why they are found on the south, and not found on the north sides of the mountains, for they would, if conditions were suitable, soon work over from one side to the other. I merely say that, given the conditions here present, the pines would certainly be first found on the south sides of mountains.

It must be said that there are some tolerably strong arguments against the view I have here advanced as to the distribution of the pines, and one of these is, that in the very section of Kentucky where the pines are found, they are by no means uniformly distributed, and oftentimes miles of low hills will intervene without a single pine, and a comparatively solitary high hill will have several on its summit. I can only suggest, in explanation of this, that the high hill-tops are the ones which would most catch the wind-carried seeds, and that, should they be dropped on the low intervening hills, they would probably not grow, unless the formation happened to be one of the dry shales. As I have previously said, my observations go to show that the pines in this part of the State (as also in the Pine Mountains further southwest) grow only on high hill or mountain tops, or else on dry shales, like the Devonian or some of the Waverly shales.

Inasmuch as the hemlock is always found within comparatively few feet, in barometric height, above *local* drainage, and is therefore usually in the hollows and ravines, rather than on the hills, we must look to the water for its distribution. Such seeds as the wind might pick up and lodge on mountain peaks certainly would not grow. To appreciate the peculiar distribution of hemlock, its characteristics must be understood. These I have studied minutely, so far as their growth in Kentucky is concerned, and am convinced—

1. That they do not grow, on the *average*, at a greater height than fifty feet above the local drainage.

2. That, nevertheless they require a *very* dry soil, the more rocky and precipitous, usually, the better. These two conditions can be satisfied only by small mountain streams,

which have a very limited extent of bottom land (hemlock will not grow on bottom land at all), and where the surrounding hills come down to the water edge, forming more or less ravines and precipices. The consequence is, that while the head-waters of the Kentucky river on the one hand, and of the Cumberland on the other, penetrate into the very heart of the hemlock region, and are the mountain streams along which this timber grows to the greatest perfection, yet the Kentucky river does not carry it far northward, nor the Cumberland river far westward. The seeds will be carried downward and deposited by these streams, and will take root and grow, just so long as the above conditions are complied with; but, whenever the streams become large enough to have a belt of bottom lands along them, the possibility of a further spread of the hemlock ceases in Kentucky. The conditions of growth of that timber may be different elsewhere.

It is worth while, in speaking of special timbers, to call attention to a somewhat remarkable forest of beeches, which occupies a belt of country eight or ten miles wide, beginning about three miles from Greensburg, and extending to within about the same distance of Campbellsville, and lying in Green and Taylor counties. The extent of the belt in other directions I could not determine. In this belt, beeches form the forest timbers to the almost entire exclusion of other growths. They not only occupy the valleys, but extend to the tops of the highest hills. The reason is to be found in the formation, which is a reddish, very much decayed St. Louis chert, out of the very top of which the water oozes, and which is therefore always wet. Inasmuch as height above drainage is the principal determinant of beech growth, it is natural that these hills should be covered with such a heavy forest of that timber.

As to the distribution of the magnolias, the so-called American laurels (rhododendron and kalmia), and the linden trees, I confess that I see no reason why they should be confined to the eastern part of Kentucky, unless it be the purely topographical one, that high mountains and deep and ragged

ravines are necessary conditions of their introduction and growth. On the other hand, all these timbers grow and flourish on ground in this part of the State, which has less of those very characteristics than grounds further west, on which they do not grow at all. So far as I can see, the only difference is, that there are high mountains in Southeastern Kentucky, and there are no high mountains in Western Kentucky. The subject of the growth and distribution of these timbers is full of interest, and should be investigated.

I should speak, also, before leaving this head, of the oaks in Kentucky and the West generally. So far as their classification is concerned, they are in a very unsatisfactory condition; and in dealing with them, our botanies are practically worthless. In all of them, the best of which are those of Gray, Wood, and Chapman, the basis of distinction is their leaf or fruit. About the former, a great deal of space is occupied discussing distinctions which do not exist at all; for the leaves of the oaks, with a few marked exceptions given below, shade into one another in such a way that it is impossible to distinguish the trees in that way. It is nearly as bad with the fruit, with the additional inconvenience that it is only for a short portion of the year that such a distinction is available at all. I am convinced that the only characteristic suitable for a basis of classification in forestry, is the bark, and that seems to have been studiously ignored by our best authorities. For my own part, while I desire to be very conservative in speaking on a subject which requires much labor and study, the more attention I devote to the oaks, the more I am inclined to believe that there is no foundation in fact for more than seven oaks in this part of the United States, viz.: white oak, black oak, red oak, Spanish oak, post oak, laurel oak, and chestnut oak. There is exceedingly small basis for a distinction between the red oak and black oak, and I question if they merit the dignity of separate species. All of the many species of our oaks, beyond these six or seven, rest, I believe, upon illusory distinctions, and can be traced through all gradations into one of the seven divisions here given. Of course, in the following pages, the usual botanical classifications have been made, as a matter of convenience.

There is an oak found near streams, and in rich woods and glens in Kentucky, which cannot be classed, according to the distinctions now in use, as a variety of red oak, nor as a dwarf oak, nor as a *Quercus lyrata*. It resembles *Q. macrocarpa* more than any other oak, perhaps, except that the leaves are not downy or tomentose beneath; but, on the contrary, are a dark, rich, smooth green, and are shining like the leaves of *Q. lyrata*. I have called it *rich red oak*, and have classified it as *macrocarpa*.

There is another oak, called by the people chinquapin oak, and which I have classed as *Q. prinoides*, on account of its very great resemblance to chinquapin oak, but which often grows fifty feet high in the mountains of Kentucky. There is also in the mountains a low, rich green oak, the bark of which is darkish to whitish gray, with long, straight, shallow furrows at the base of the tree, growing more deep and chipped up the stem; branches smooth, gray, with brownish rough spots or dots; acorn broader than long, dorsally compressed, and one fourth buried in a brittle, scaly, flat cup. The leaf lobes are 7, 9, 11 in number, and are awned. The little tree is very rich in fruit. I have called it *Q. ilicifolia*, on account of its great resemblance to that species, though it differs from it in some respects.

TIMBER IN DETAIL.

A mere running sketch of the Purchase country and its timbers will be given here, because a special report on the timbers of this section has been prepared and published, to which the reader is referred for more detailed information. (See Report on Purchase Timbers, volume V, this series.)

In going eastward from Columbus, on the Mississippi, no timbers worthy of special mention are met with for some miles. The old forests have been cut away. About one and one quarter miles out the country is rolling, the soil white-sandy and damp, with large white oak and liriodendron

in low places, as well as black ash, black gum, sweet gum, black and red oak, pawpaw, black sumach, and redbud. Undergrowth is chiefly black oak and red oak. These timbers vary little until Bole's Creek is reached, about three miles from Columbus. On the creek are found sycamore, red elm, liriodendron, white oak, black and honey locust, sweet gum, white walnut, small black walnut, and considerable sugar maple and black ash.

Five miles out from Columbus, toward Mayfield, the forests grow heavier and more valuable, white oak forming a considerable percentage of the timbers (as much as fifty per cent. in low places), liriodendron about twelve per cent., the remainder being composed of black and pig hickory, red oak, black oak, some scarlet oak, white and red elm, sweet and black gum, and sycamore. The country is rolling, with long, damp, white-sandy levels.

About five and three quarter miles out the first swamp laurel oak, the first white maple, and the first winged elm of any size are found. On Elsey Branch, a mile further on, shag hickory and pin oak first appear—the latter very large and fine. The other timbers remain as above noted, with occasionally a fine black ash.

Eight and one half miles from Columbus one prickly ash occurs. The timbers otherwise remain without change until North Fork of Obion river is reached, eleven miles out. There the first swamp chestnut oak appears. Spanish oak also begins to grow very prominent in these forests, and to form more than one half of the upland oaks. The first post oak seen appears between North Fork of Obion river and Milburn.

Four miles beyond Milburn, toward Mayfield, the Purchase pebbles come to the surface, and a thin, dry soil, covered with post oak, scrubby black oak, &c., is the result. These pebbles are the waste of the decayed mill-stone grit, and are found in every part of the Purchase at a greater or less depth below the surface. Upon it white oak is not found; but while, as a formation, it is very dry, it brings the streams to the surface, and along them in this locality grow the first red or water birch met with. About seven miles from Milburn, on these surface streams, pin oak is found in the greatest abundance, while post oak and black-jack crown the low, gravelly hills. An occasional spotted birch is found along the foot-hills, and considerable willow along the branches.

About eight miles from Milburn, and midway between there and Mayfield, the present "barrens" of the Purchase are entered. For a discussion of them, see the report on the Purchase timbers previously alluded to. While some of the views and the limits there expressed have been modified by later study, that is not true of the *cause* of the original barrens there given. The boundary of the present barrens, between Mayfield and Cadiz, seems to be, in this locality, Mayfield Creek; but this is not true further south, between Mayfield and Murray. I have already given reasons for believing that all the upland of the Purchase has, in former times, consisted of barrens.

On Mayfield Creek splendid cypress trees are found, associated with liriodendron, red birch, white and red elm, sweet gum, sycamore, black ash, pin oak, white oak, black gum, black hickory, &c., while in the upland forests beyond, toward Cadiz, post oak, scarlet oak, black oak, and black-jack are the principal timbers. On Panther Creek the timbers common to Mayfield Creek, with the exception of cypress, are again found. There is a marked absence also of sweet gum, for which I could assign no cause. On the hills through here grow white oak (at bases), red oak, black oak, and Spanish oak (about midway), and scarlet oak, post oak, scrub shag hickory, and black-jack (on top). The hickory here spoken of is a mountain variety of *Carya sulcata*. [The distribution of the timbers, as affected by height above drainage, will be illustrated by tables and discussed further on in this report.]

Before reaching the West Fork of Clark river, I found two chestnut bushes, about six inches in diameter, which had evidently sprung up from chestnuts dropped by passers-by. They had grown up to this size, and both had died, without

any apparent cause, except that the formation, in its *present condition*, is not adapted to chestnut growth. This matter has been previously discussed.

The timbers on West Fork of Clark river have been spoken of especially in a previous report, and do not need mention here. After passing the river the barrens continue, without interruption, except on small streams, until Wadesboro is reached and passed. The shrub spirea is found near Wadesboro. On nearing East Fork of Clark river, about one mile beyond Wadesboro, considerable good timber is found, consisting of white oak, liriodendron, white ash, black and pig hickory, Spanish, scarlet, black, and post oak, dogwood, persimmon, pawpaw, black sumach, spotted birch, sassafras, &c. On Clark river the usual swamp timbers appear in vast forests, and of the finest proportions. Sweet gum, black gum, shag and white hickory, white oak and liriodendron are especially fine.

After crossing Clark river, white oak is tolerably abundant, often extending to the hill-tops. This would seem to indicate that a *part* of the strip of country between West Fork of Clark river and Tennessee river, as well as the strip previously mentioned, between the Tennessee and Cumberland rivers, was never swept by fires to the same extent as those parts of the Purchase west of this fork of Clark river. This inference is still further strengthened by the existence of considerable chestnut all through here. It may be that the fires from the west did not penetrate across West Fork of Clark river, while those from the east found a western barrier in the Cumberland river. A fact to be mentioned presently, however, throws some doubt upon this, and leads me to believe that, at times, the fires swept across both of these streams.

About one mile from the Tennessee river we strike the *Protean* or the *Silicious group* of rocks, without any marked change in the timbers. In the Tennessee river bottom are found splendid groves of cypress, from three to seven and one half feet in diameter, nearly always standing in marshy places, in a few inches of water, with their knees reaching just noted, except that some red haw and winged elm are found. There is no white oak, no sweet gum, no chestnut (that I could find), and no liriodendron. On Pilot Rock, northeast of Hopkinsville, which is a lofty bluff of Big Clifty sandstone, cedar and liriodendron are both met with; but this is very local, and even here no chestnut is to be seen, so far as I could gather.

Between Fairview and Elkton the timbers, as a whole, are not valuable; but in places black ash, white elm, pig and shag hickory, and such timbers, are exceedingly fine. Especially is this true on West Fork of Red river, about one and one half miles from Fairview. On this stream are also found splendid white oak, swamp chestnut oak, red and pin oak, white and shag hickory, black and blue ash, sweet gum, liriodendron, white elm, sycamore, box-elder, sugar maple, white maple, and redbud. All of these timbers are very fine. It is a peculiar, though an easily-explained fact, that in a large part of the country through here the timbers are better on the hill-tops than on the lower grounds. The reason is, that the hills are capped with Chester sandstone, the detritus of which forms a damp soil, favorable for large trees, while the upper St. Louis limestone here is not adapted to timber growth.

Toward Elkton, scattering bartram oaks and cedars are found, in addition to the usual red oak, shag hickory, pig hickory, white hickory, winged elm, small black ash, scrub white oak (in spots), Spanish oak, black oak, post oak, black gum, &c. Yellow wood is also found near Elkton, with some honey locust, redbud, and red (slippery) elm. Of course the swamp timbers have never been affected by fire; and on streams fine white oak, liriodendron, white and sugar maples, sweet gum, laurel oaks, &c., flourish. The upland and lowland timbers alternate, with no changes worthy of note, until Russellville is reached—and there our party took the train and went by rail to Glasgow Junction.

Between Glasgow Junction and Mammoth Cave the topography is very different from that spoken of in the previous pages. There is no well-defined succession of hills and hol-

lows, the result of erosion, through the latter of which the streams of the country flow. The formation is a cavernous Saint Louis limestone, the roofs of whose caverns have given way in many places and let the surface of the ground fall in, forming regular sink-holes, more or less circular in form, often of the dimensions of wide and deep hollows, but with no outlets. There are no surface streams, and into these sink-holes the surface water flows, and the detritus washes and accumulates. It is natural to expect in such places the most splendid timbers, and such are often found there.

Again, forest fires have evidently not denuded certain parts of the country in the neighborhood of Mammoth Cave. What is known as Doyle's Valley, for instance, has been, for some reason, largely protected from the ravages of fire, even if the entire district has not been. From the growth of chestnut, I am inclined to think that it has never been continuously burned over.

On leaving Glasgow Junction, toward Mammoth Cave, plenty of white oak is found in the sinks; post oak, black oak, scarlet oak, and red oak are found on the higher grounds, and as soon as Chester sandstone, which caps the so-called hills, is reached, chestnut is found in great abundance. This is the first chestnut worthy of note found, and all that has been found, so far, if a few bushes on the silicious limestone, near Tennessee river, be excepted; though doubtless all this Chester sandstone, from Hopkinsville to Glasgow Junction, would have been covered with it, but for the fires that long ago swept over this richly timbered country, year after year, and drove its choicest trees from the forests.

On the hill sides facing Doyle's Valley the trees are magnificent, and white oak, liriodendron, white hickory, massive chestnut, scarlet oak, red oak, black oak, Spanish oak, chestnut, ashes, redbud, &c., abound. The chestnut, however, is limited to the sandstone, and stops abruptly when the limestone is reached in descending the hill.

On nearing Mammoth Cave, and all along the banks and cliffs of Green river, hornbeam (*Carpinus Americana*, often called iron-wood, but not the true iron-wood) and hop hornbeam (true iron-wood) abound. On the long, high level above the cave the principal timbers are red, black, and Spanish oak. They are worthless except for fire-wood.

In the immediate vicinity of Mammoth Cave, and crowning the hill-side facing Green river, above and below it, the timbers are red oak, liriodendron, chestnut (on sandstone or its detritus), white hickory, white oak, black walnut, blue ash, an occasional sugar and rock maple, winged elm, &c. At the base of the hill, on Green river, are beeches, sycamores, spice-wood (the first met with), white hickory, liriodendron, and white oak. Black sumach, woodland huckleberry, buckeye, dogwood, &c., are among the small growths.

About two miles from Mammoth Cave, toward Cave City, the hill-tops are poor, and are covered with Spanish oak, scarlet oak, black-jack, and an occasional mountain oak. In the sink-holes and on their steep sides grow splendid chestnut, pig and white hickory, liriodendron, some white oak, post oak, and black locust. The chestnut is found only on the sandstone. These upland and lowland timbers alternate, without any changes worthy of note, except occasional swamp chestnut oaks, Bartram oaks, laurel oaks, and black hickory, until we begin to pass into the present eastern barrens, about twelve miles from Cave City, and within about eighteen miles of Greensburg. White oak and chestnut cease to exist, except the former on streams, &c., and a repetition of the barren timbers of the Purchase occurs. There seems to be a neck of country about Mammoth Cave which has, for some reason, more or less escaped the ravages of fires.

Nothing else of interest occurs until we begin to pass from the cavernous St. Louis limestone onto the Keokuk limestone, sixteen or eighteen miles from Cave City. The change of formation first attracts attention by the circular sinks beginning to fade away into valleys, and the steep cave-hills into the more gently-rolling ones, due to erosion. The normal hill and valley topography gradually succeeds again the wonderful cavernous district, of which Mammoth Cave is the most widely known, if not the most interesting and instructive part.

The Keokuk is an exceedingly fertile formation, and its timbers are nearly always, on the limestone, of the finest. Its soils are rich in marls, it furnishes a good supply of surface water, and has all the requisites for the production of splendid forests. Timbers, therefore, grow better and more valuable at once on passing onto the Keokuk ; but white oak, chestnut, and most of the liriodendron, have been driven from the forests in this locality by fire. With these exceptions, the hill-side facing Little Barren river on the west furnishes a good sample of the timbers that grow on the Keokuk limestone. They are black cherry, black locust, swamp chestnut oak, black walnut, some liriodendron, white and shag hickory, sycamore, mulberry, blue ash, red elm, white maple, redbud, water beech, hackberry, and cedar. On the same formation, immediately after crossing Little Barren river, plenty of chestnut and white oak are found, with scarlet oak, black oak, pig hickory, and sugar maple, in addition to the timbers just mentioned above; and all through the hills white oak, chestnut, and liriodendron become exceedingly fine and valuable. This points to the probability that Little Barren river was the eastern barrier to the ancient fires.

On nearing Green river, about five and one half miles from Greensburg, the forests are magnificent. They consist of large liriodendron, white oak, shag hickory, white hickory, black walnut, beeches, swamp (rich) red oak, hackberry, honey locust, red elm, box-elder, blue ash, sugar maple, water beech, and swamp chestnut oak. In the swamp, in addition to these, are black locust, big buckeye, and black ash.

After crossing Green river, we ascend again onto a somewhat sharply-rolling country, whose bed rock is very much decayed St. Louis chert, and whose timbers, for several miles, are nearly altogether beeches. This peculiar beech growth, occupying alike the highest hills and the lowest grounds, has already been spoken of.

About five and one half miles from Greensburg, toward Campbellsville, the beeches begin to give way to black oak, red oak, liriodendron, chestnut, pig and black hickory, swamp chestnut oak, white oak, blue ash, &c.; and within about three miles of Campbellsville white oak forms as much as fifty per cent. of the splendid forests. Scattered through the woods are also found white walnut, tree of Paradise, fine black walnut, black cherry, iron-wood, shrub buckeye, big buckeye, red-bud, sassafras, dogwood, red oak, Spanish oak, scarlet oak, chestnut, red haw, black sumach, and pith elder. The entire absence of sweet gum, even from the swamps, all through the country, from the Cumberland river eastward, will have been noticed. I could find no satisfactory reason for it.

A long, dry shale level, covered principally with black, Spanish, and scarlet oak and black hickory, begins within about nine miles of Mansville (Buena Vista). Occasionally the shale is cut across by small streams, and in the depressions white oak, laurel oak, water beech, winged elm, spotted birch, and some chestnut are found. In some of these depressions, where the shale is always moist, the forests are very heavy, and white oak, chestnut, liriodendron, pig and white hickory, black and Spanish oak, &c., abound. About three miles from Mansville, post oak and sweet gum are met with again.

At Mansville, on Robinson's Creek, we pass onto Devonian shale, and the timbers become nearly worthless, except on streams where the usual lowland timbers are found.

About three miles beyond Mansville, toward Stanford, there is a small belt of country, less than half mile in breadth, on which thirty per cent. of the undergrowth is white oak. I have seen only two or three other spots in the State where any considerable proportion of the bushes consists of that timber. The tops of the hills in this locality are covered with post oak, scrub black oak, huckleberry, &c.; and the first mountain chestnut oak seen east of the Cumberland river is here found. Pith elder and black sumach inhabit the fence-rows, with occasionally a shrub buckeye, some bushes of winged elm, &c. The hills, in a wholly Devonian shale formation, are always low, and their timber growth is comparatively worthless, such as scarlet oak, post oak, Spanish oak, scrub

black oak, and scrub hickory. On low grounds considerable white oak, pig hickory, and winged elm are found, but they are not valuable.

About five and one half miles from Mansville, we pass from the Devonian shale onto the underlying Corniferous limestone, of which there is a layer of only three to five feet in thickness in this locality. Underlying this again is the so-called Cumberland sandstone, a bluish, silicious, almost semi-limestone formation. The only immediate change of timber noticed was the introduction of a few swamp chestnut oaks, and their presence cannot be attributed merely to change of formation. Some white and sugar maples appear on low grounds, with sweet and black gum, white oak, red oak, and iron-wood.

On the Cumberland sandstone liriodendron again becomes a conspicuous timber, and the forests become much better in every way. On a large hill, about seven miles from Mansville, the woods are exceedingly rich. The principal timbers are blue ash, Ohio buckeye, black walnut, white and shag hickory, liriodendron, and white oak. Big buckeye forms from forty to seventy-five per cent. of the timbers in this rich forest. On the eastern face of this chain of hills, not far above its base, and about ten miles from Mansville, we pass onto the Cincinnati limestone. The timbers do not vary in kind from those given above, and there are no changes for several miles, except that occasionally a hackberry or an aspen is seen.

Taken as a whole, the standing forests are poor and valueless all along South Rolling Fork. The formation alternates between Cumberland sandstone and Cincinnati limestone—first up onto the former, then down onto the latter, and so on. All through the valleys the timbers have been cut away, and on the hills they are worthless.

At about six miles south of Hustonville (twenty miles from Mansville), there is the largest forest of bartram oak I know of in Kentucky. The valuable timbers are all cut away, on low and high grounds alike. The standing forests are worthless, and are likely to remain so, unless a thrifty cultivation and protection soon succeed the long-continued destruction.

At about two miles south of Hustonville the Cumberland sandstone dwindles away to a shaly bed about ten feet in thickness, overlaid by heavy deposits of Corniferous; and in starting through "Nigh Gap," it gives out altogether, and the overlying Corniferous rests directly upon the underlying Cincinnati limestone. "Nigh Gap" is the passage-way over Muldraugh's Hill, starting from Rolling Fork. The base of the hill here is Devonian shale, which is succeeded by Keokuk limestone at a height of seventy-five barometric feet. The transition presents a marvelous change in the timbers, and brings into strong contrast the difference between these two geological formations, in their effects upon forest growths. On the shale the timbers are mountain chestnut oak, scrub white oak, sour-wood, red oak, a few beeches (right on the river), some rock maple, &c. On the Keokuk, immediately adjoining, and on a higher level, grow splendid forests of white oak, black hickory, chestnut, black locust, liriodendron, white and shag hickory, sugar maple, redbud, spicewood, mulberry, blue ash, black ash, black cherry, American linden or bass-wood (the first met with), black walnut, red haw, and the usual small growth. The exceeding variety and richness of these Keokuk timbers is worthy of note. As to the questions pertaining to distribution, as affected by height above drainage, they become of the first importance from this point eastward, and will be discussed and illustrated under a separate head further on in this report.

After crossing Muldraugh's Hill, we enter the counties (north part of Lincoln and Garrard) the forests of which have been almost completely cut away. There are only scattering patches of fenced-in groves, consisting mostly of black and blue ash, white oak, black walnut, pig and shag hickory, and hackberry, until Muldraugh's Hill is reached again, near Big Hill, in the southern part of Madison county. The geological changes are numerous. Stanford rests on Cincinnati limestone, and this continues to be the formation in depressions for some distance. On the higher grounds Cincinnati (?) sandstone appears. Between Paint Lick and Irvine, and

about twenty-nine miles from the latter place, we pass from Cincinnati up through about ten feet of Corniferous onto Devonian shale. Hackberry is found scattered all through the country.

About twenty-seven miles from Irvine the formation is still Devonian shale; but its detritus forms a long, whitish level, on which, in choice local spots, considerable white oak is found. Timbers are chiefly poor and valueless.

We strike the Corniferous again near Silver Creek, about two miles west of what is locally known as Johnson's Shop; but we pass onto Devonian shale again on Silver Creek. Pawpaw bushes, black sumach, and scrub buckeye are found in the greatest abundance all through here, together with some laurel oak and post oak. The valuable timbers have all been cut out.

Near Big Hill, while Devonian shale is still the lowland formation, Waverly (Keokuk) shales are the foot-hill formation. The tops of the high hills, such as Big Hill and Buzzard's Basin, are capped with Conglomerate; so that we have a complete geological section, from Devonian shale to Conglomerate, on one of these hills. Here the first pines (*pinus mitis*) are met with on the journey eastward. They crown Big Hill and other high points, and are found on the dry, thin shales of the foot-hills.

After leaving Big Hill post-office, toward Irvine, on Red Lick Fork, red birch, holly (the first noted), sweet gum, white oak, Spanish oak, red elm, spotted birch, service berry (*Amelanchier*), laurel oak, black ash, willow, red oak, cedar, shag hickory, sugar maple, buckeye, pine, box-elder, redbud, black gum, pawpaw, and sour-wood are met with. A large part of the valley timbers is still cut away. Some American linden is found on the high knobs between Big Hill and Irvine, associated with fine black walnut, white oak, white hickory, and liriodendron, about the heads of the numerous little branches that flow from the hill-sides. The timbers remain without essential change to Estill Springs.

After passing Irvine, and turning up the Kentucky river toward Beattyville, the formation is successively Devonian (on lower spots) and Waverly (chiefly cortigalli). The forests for some miles are not very valuable. A low, dark green, exceedingly fertile mountain oak (*Quercus ilicifolia?*) appears in great abundance on the hill-sides, and about five miles from Irvine hemlock is first seen. Fine pig hickory, white oak, Spanish oak, red oak, blue ash, green ash (only one), sugar maple, buckeye, liriodendron, white hickory, and red elm are scattered all along the river and mountain sides. The timbers remain pretty much the same for three or four miles, when the first magnolias (cucumber trees) are met with. Associated with them are Ohio buckeye, black ash, redbud, winged elm, liriodendron, white maple, water beech, green dogwood, amelanchier, rhododendron, and kalmia (the first of these laurels found), red elm, spotted birch, red oak, mulberry, white oak, walnut, cedar, red sumach, and pawpaw. The formation is Keokuk.

All of the hill-sides near Irvine are covered with splendid forests of black and blue ash, pig, shag, and white hickory, liriodendron, sugar maple, white oak, bartram oak, sycamore (on streams), box-elder, red elm, some American linden, magnolias (*cucumber* and *Frazeri*), red birch, mulberry, sweet gum, big buckeye, and catalpa.

About fourteen miles from Irvine, toward Beattyville, the river valley contracts and becomes very narrow, the hills close in on all sides, and we pass through a deep ravine, the escape from which is over what is widely known, locally, as the "Winding Stairs." In ascending the Winding Stairs, the following timbers are found: linden, black and blue ash, rich red oak, chestnut, white oak, liriodendron, white maple, white and black walnut, white hickory, pig hickory, magnolias (umbrella and cucumber), black birch, black gum, water beech, dogwood, mountain chestnut oak, spicewood, willows (near a spring), rhododendron, kalmia, azalea (*nudiflora* and *viscosa?*), Amelanchier (two varieties), pines (*mitis* and *rigida*), black oak, scarlet oak, black sumach, sassafras, and dogwood. The chestnuts begin as soon as Chester sandstone is reached, in ascending the hill. The timbers here given are nothing more than a fair average, and all of them may be found on any high hill in this part of the State.

After reaching the top of the Winding Stairs, there stretches out a long, irregularly-level expanse of country, on which the timbers are not worth special mention. From this level the road descends to Lower Stufflebean Creek, about two and one half miles from Beattyville. The formation is Sub-conglomerate shale, varying into Conglomerate sandstone. The timbers are not noteworthy, except that holly and swamp alder appear in considerable quantities.

For several miles beyond Beattyville, toward Jackson, no great changes in the forests occur, and the timbers are such as are usually met with on the lowlands. We follow the Kentucky river tolerably closely for a considerable distance. About three and one half miles from Beattyville, along the river bank, grow perfect thickets of pawpaws, which often reach a height of fifty feet! With them, and along the foot-hills, grow red and white elm, sycamore, black and blue ash, linden, big buckeye, water and common beech, liriodendron, hemlock, swamp alder, pith elder, red oak, iron-wood, amelanchier, sweet gum, golden alexander, red and black haw, and hawthorn. On the higher hills are post oak, black oak, red oak, scarlet oak, mountain oak, black locust, and the usual hill timbers. About five miles from Beattyville the forests of white oak are as fine, along the rich hill-sides, as I ever saw. Hickories are splendid also, and walnut, liriodendron, chestnut (on sandstone formations), and linden are unsurpassed along all the ravines whose waters head in the rich woods below the brows of the high hills. The tops of the hills are crowned with black oak, scarlet oak, mountain chestnut oak, rock maple, scrub hickories, and pines.

The splendid timbers given above continue, with only local breaks, all along Lower and Upper Twin Creeks, and the hills through which they flow. The latter stream empties into Middle Fork of Kentucky river, within about twelve or thirteen miles of Jackson, Breathitt county; and at its mouth the road leaves the river and turns up it, follows it to its head, crosses the divide at its head waters, and descends onto West Fork of Cane Creek, down which it follows toward North Fork of Kentucky river. The timbers all through these high, abrupt, and inaccessible hills, and deep, rich, ravine-like hollows, are scarcely surpassed in the State. A considerable amount of fine old forest walnut, black birch, and cherry still stand in these fastnesses, and gigantic liriodendrons, white oaks, ashes, lindens, locusts, chestnuts, elms, buckeyes, magnolias, and maples have, so far, bid defiance to the axes that have laid these timbers waste in other parts of the State. Civilization has not yet penetrated into these forest wilds, and the grandeur of the trees and the silence of the woods make a striking impression upon one.

The tall, dark, rich-green oak spoken of heretofore, and which I have called *rich red oak*, flourishes all through these woods. It is probably the *macrocarpa* of the botanies. A few hackberries, considerable gray birch, some white pine, &c., are met with.

High up on Upper Twin Creek, about seven miles from Jackson, on a hill-side facing north and east, at a barometric height of thirty-five feet above the small stream below, a rich belt of black walnut trees encircles the hill. There are not a great many trees in the belt, but some of them are exceedingly fine. Beds of coal are found along Upper Twin Creek, and the formation is coal-measure sandstone. All through the woods there is found, in great abundance, a hickory which I have called *microcarpa*, because it is evidently a variety of the "white hickory" of former reports on Kentucky timbers. It is a tall, clean-trunked, fine-bodied tree, branching high; bark comparatively thin, nearly smooth right at base, where the shallow interspaces of the bark are nearly straight, or only slightly chipped, but considerably more chipped higher up the trunk; leaves linear, acute at base, lance-tipped, serrate and smooth, except slightly downy at base of veins.

From Jackson to the mouth of Troublesome Creek, seven miles out toward Hazard, we pass right along North Fork of Kentucky river, with the usual lowland timbers along the river, and no changes of moment on the hills. Our route now lay up Troublesome Creek to Lost Creek; up Lost Creek to its head waters, across the divide onto Lot's Creek, and thence to Hazard. The hill timbers along this course are very similar to those already given on Twin Creek, and the forests are everywhere of the finest. The question of distribution, as affected by height above drainage, which is the most important one that presents itself in this part of the State, will be, as I have previously said, illustrated and discussed separately.

A list of the timbers noted in the Troublesome Creek region, includes white, black, and pig hickory, white oak, holly, black and blue ash, white ash, black walnut, liriodendron, chestnut, black gum, black and gray birch, winged elm, white, rock, black and mountain maple, redbud, mulberry, red oak, black oak, mountain chestnut oak, scarlet oak, beeches, black cherry, hawthorn, red haw, big buckeye, black locust, linden, water beech, silver poplar, cucumber and umbrella trees, swamp chestnut oak, sycamore, bartram oak, scrub red oak, magnolia (*Frazeri*), pines, cedar, hemlock, elm (*racemosa*), American laurels (rhododendron and kalmia), spicewood, papaw, pith elder, willows, persimmon, dogwood (green and low cornel), black sumach, and swamp alder. The *scrub red oak* is probably the *ilicifolia* of the botanies. The great variety, and the richness in valuable timbers, of these forests, I think, can scarcely be surpassed. The formation is coal-measure sandstone.

The timbers above given are found, with local variations and alternations, until North Fork of Kentucky river is reached again at Hazard. The usual swamp timbers are there found, and, in addition to them, hazelnut, aspen, and Solomon's seal.

After passing Hazard, the road follows North Fork of Kentucky river about six and one half miles, to the mouth of

Carr's Fork. It then turns up that stream, follows it for about ten miles, crosses over the divide onto Rockhouse Creek, and strikes the Kentucky river again at Whitesburg, thirty-five miles from Hazard. The upland and lowland timbers between these two places are precisely the same, with the addition of wintergreen and white willow (*Salix candida*), as those given in the Troublesome Creek region. The old forest walnut is scarce; but it is exceedingly large, and of good quality, on the heads of most of the streams, far up under the brows of the high hills. White linden and ironwood are found. The former has not been met with previously, but it abounds on the mountains to the southwest.

In about ten miles of Whitesburg quite a marked change in the distribution of the hill timbers occurs. The formation remains coal-measure sandstone; but the surface soils of the hills are a thin, whitish shale detritus, very poor, and there are no damp, dark, rich hill-sides, covered with splendid lowland timbers nearly to the top. The swamp timbers are narrowly confined to the margins of the streams and to the bottoms. In other words, the line of comparative moisture, if such line be imagined, has been removed down the hills; so that, to find a belt of given moisture, one would have to look much nearer the bases of the hills. A corresponding effect is, of course, produced upon the timbers.

In passing over the divide between the head waters of Kolley's Branch and Sandy Lick, within about seven miles of Whitesburg, the road circles around the head of a branch which flows from a deep ravine to the left (northeast) of the road. Just above the head waters of this branch, on the steep hill-side, grow some of the finest liriodendron and black walnut trees I have seen in Kentucky. One of the former reaches the enormous size of eighty inches in diameter, with fifty feet of clear, straight trunk. The walnuts are thirty-eight to forty inches, with fifty to sixty-five feet of beautiful body. White oak, white and pig hickory, buckeye, and other timbers, are proportionately good and valuable. A few "burning bushes" (*Euonymus Americana*) are also found. The formation is coal measures.

At Whitesburg the North Fork of Kentucky river is reached again, and for some distance beyond the road follows the river pretty closely. The usual lowland timbers, of which lists have been given, are met with. A great deal of sweet gum is found in localities, especially about five miles from Whitesburg. The hills near the river are largely covered with poor sandstone shale, and the timbers are not very good. At a distance from the river, however, the hills are richer, and the forests are very valuable. Considerable white walnut and black birch are found all through the woods. Otherwise, the timbers remain comparatively unchanged, until the head waters of North Fork of Kentucky river are reached, at the base of the mountain below Pound Gap.

On the mountain sides near Pound Gap and along the dark, rich ravines, stately and beautiful walnut, linden (American and white), black birch, black cherry, white oak, liriodendron, hickories, and most of the valuable forest timbers of the State, flourish in the greatest abundance. The ancient forests stand unharmed by the ax, and are likely so to remain for some years to come.

About three quarters of a mile from Pound Gap, the road crosses the Pine Mountain fault, and we pass at once from the coal measures to Devonian shale. The shale is only a narrow strip, however, and we are soon on the overlying Keokuk, and, inasmuch as that is one of the richest timber-producing formations in the State, growing alike the timbers of the limestones and those of the sandstones, the splendor of the forests is only slightly interrupted. When I speak of the Keokuk being one of the richest timber-producing formations known, I have reference to the Keokuk limestones of the East, for the Waverly shales are among the poorest of all formations—as dry, thin, and unproductive as the Devonian shales.

The observer will notice, all through this part of Pine Mountain, that there are two belts of pine trees. The mountain pine (*P. pungens*) and the pitch pine (*P. rigida*) are found on the dry, sandy bluffs and tops of the mountains; the long-leafed pine (*P. palustris*) and the yellow pine extend further down on the mountain slopes.

At Pound Gap we pass across from Kentucky into Virginia, and at the base of the mountain, on the Virginia side, flows Pound Creek. We follow this stream to Indian Creek, thence turn up Indian Creek to its head waters and across to Gladesville. As soon as we pass Pine Mountain into Virginia, the hill-sides are covered with chinquapin (*Castanea pumila*), not one of which has, so far as I could discover, crossed the mountain northward. The chinquapins do not extend up nearly to the top of Pine Mountain, and evidently the climate is too cold for them, and this mountain is their northern boundary. They are found in the greatest abundance all through the woods of Virginia, and southward.

The magnolias begin to die out after crossing Pine Mountain, though a few are found along shady ravines and on rich hill-sides in Virginia. The coal measures reappear again at a short distance from Pound Gap, on the Virginia side, and thence we pass onto the Conglomerate, which lasts nearly to Clinch river. There a fault of ten thousand feet, running along the line of Clinch river, brings up abruptly the Knox limestone, and between there and Abingdon, Virginia, a succession of faults causes an almost constant alternation of the Cincinnati and Knox limestones. The forest timbers are not, upon the whole, so good as are those on the north side of Pine Mountain, in Kentucky; but they are everywhere valuable, and there is no marked difference in kind, other than those noticed.

TIMBER DISTRIBUTION AS AFFECTED BY HEIGHT ABOVE DRAINAGE.

Although the data for this report have been prepared with special reference to a discussion of the effects of height above drainage upon timber growth, and, with that object in view, the following tables have been arranged, nevertheless it is necessary to point out some of the dangers of generalizing

from such data, and especially some of those disturbing elements which render investigation in this particular direction liable to error. The first, and probably the most important, of these is sudden and abrupt changes in the nature and relative hardness of different parts of the same formation. In fact, to this cause is due, almost altogether in *hills*, and very largely in *mountains*, height above drainage itself; but it is in a narrower sense that it becomes a disturbing element in discussing timber growth. The sudden cliffs and benches on hills and mountains are caused by difference in hardness of two successive strata; and a cliff of exceedingly hard rock, or hard, dry soil, even when near the base of a hill, will often be permanently drier than a bench or hill-top barometrically much higher above drainage. The hardness of such a cliff prevents the formation of detritus and the retention of water For this reason a softer formation or bench, easily worn away, and capable of forming a surface detritus which will retain moisture, is, so far as effect upon timber growth is concerned, nearer to water than a hard cliff hundreds of feet below it.

Another disturbing element is sudden change in geological formation. One of the dry shales, like the Devonian and some of the Waverly shales, will cause as much change in timber growth as would be produced by the greatest height above drainage attainable in our mountains. Of course the change might be different in character, but in amount it would be as great. Changes of this nature, though, can usually be guarded against in gathering data.

The natural difference in shade, moisture and coldness, between the northern and the southern faces of hills, also produces its effect upon the timber growth. All of these disturbing elements have been taken into consideration, and accounted for, as far as possible, in preparing the following tables. The liability to slight error, however, should be kept in view.

In the tables, "N. F.," "S. F.," &c., under the barometric height at the head, mean, respectively, "North Face," "South Face," &c., of the hill.

TABLE No. 1.

Barometric height.	Location.	Formation.	Timbers.
1350 feet.	Foot-hill in Trigg county, about one mile from Tennessee river.	Silicious Limestone.	White oak (fifty per cent. of timbers), red oak, black oak, black and pig hickory, iron-wood, black gum, dogwood, and Spanish oak.
1390 feet.	Same on hill-side.	Same.	Black oak (sixty per cent. of timbers), Spanish oak, pig hickory, black hickory, and scrub oak.
1400 feet.	Same.	Same.	Same, with mountain chestnut oak.
1410 feet.	Same.	Same.	Same, with post oak and some chestnut.
1460 feet.	Bench of hill.	Same.	Mountain chestnut oak (forty per cent. of timbers), black oak, scarlet oak, post oak, and chestnut (only one).
1485 feet.	Hill-top.	Same.	Black-jack, mountain chestnut oak, and scrub black oak.

TABLE No. 2.

Barometric height.	Location.	Formation.	Timbers.
1290 feet. (E. F.)	Foot-hill four miles from Tennessee river.	Silicious Limestone.	Sweet gum, white elm, white oak, rich red oak, pig hickory, and white hickory.
1375 feet.	Hill-side.	Same.	White oak, rich red oak, black hickory, and pig hickory. Sweet gum and elm have given out.
1430 feet.	Same.	Same.	White oak, pig, shag, and white hickory end. Post oak, black oak, and Spanish oak begin.
1475 feet.	Hill-top.	Same.	Black-jack, scrub Spanish oak, post oak, and scarlet oak.

TABLE No. 3.

Barometric height.	Location.	Formation.	Timbers.
1375 feet. (W. F.)	Foot-hill 3½ miles from Cumberland river.	Saint Louis Limestone.	Liriodendron, white oak, red oak (one only), sweet gum, sugar maple, and red maple.
1450 feet.	Hill-side.	Same.	Liriodendron, black oak, pig and black hickory, and red maple. Sweet gum, white oak, and sugar maple have disappeared.
1495 feet.	Bench of hill.	Same.	Scarlet oak, black oak, post oak, and black-jack.
1538 feet.	Hill-top.	Same.	Post oak and black-jack.

TABLE No. 4.

Barometric height.	Location.	Formation.	Timbers.
1315 feet.	Base of small hill of representative timbers, 5½ miles from Hopkinsville.	Calcareous Limestone.	Bartram oak, swamp laurel oak, pig hickory, post oak, and red haw.
1325 feet.	Hill-side.	Same.	Post oak, pig hickory, black oak, scarlet oak, black-jack, and upland laurel oak.
1350 feet.	Same.	Beginning of Chester Sandstone.	Black oak, scarlet oak, Spanish oak, pig hickory, and black hickory.
1390 feet.	Hill-top.	Chester Sandstone.	Scarlet oak, post oak, black oak, and Spanish oak, predominating in order given.

TABLE No. 5.

Barometric height.	Location.	Formation.	Timbers.
1452 ft. (S. W. F.)	Foot-hill two miles from Elkton.	St. Louis Limestone.	White oak, red oak, pig and shag hickory, white and winged elm, bartram oak, yellow wood, and red oak.
1520 feet.	Hill-side.	Same.	Post oak, blue ash, redbud, yellow wood, and hickories.
1540 feet.	Hill-side.	Same.	Same, except hickories end, and black-jack begins.
1560 feet.	Hill-side.	Top of St. Louis Limestone.	Hickories, post oak, and black-jack on Sandstone. (Note.—Reappearance of hickories on Sandstone.)
1625 feet.	Hill-top.	Chester Sandstone.	White oak (one), black oak, hickory, and black-jack.

TABLE No. 6.

Barometric height.	Location.	Formation.	Timbers.
920 feet.	Foot of average hill, ten and three fourths miles from Greensburg.	Upper Keokuk and Lower St. Louis Limestones.	Splendid white oak, liriodendron, pig hickory. and white hickory.
970 feet.	Hill-side.	St. Louis Limestone.	Same, except hickories and liriodendron end, and scarlet oak and black oak begin.
1050 feet.	Hill-side.	Damp, rotten St. Louis Chert.	White oak, chestnut, black oak, red oak, and scarlet oak.
1070 feet.	Hill-top.	Same.	Same, with Spanish oak.

TABLE No. 7.

Barometric height.	Location.	Formation.	Timbers.
1120 feet. (S. F.)	Knob about 9 miles from Mansville—base.	Cincinnati Limestone.	Splendid liriodendron, white oak, rich red oak, blue ash, black walnut, white and shag hickory, sweet gum, and buckeye.
1138 feet.	Hill-side.	Cumberland Sandstone begins.	Same, except sweet gum ends.
1240 feet.	Hill-side.	Devonian Shale begins.	White oak, black oak, red oak, mountain chestnut oak, pig hickory, mountain maple, and spicewood—all on top of Cumberland Sandstone.
1285 feet.	Hill-side.	Devonian Shale.	Scarlet oak (very large percentage), post oak, black-jack, huckleberry, and dogwood.
1380 feet.	Hill-side.	Top of Shale bluff.	Mountain chestnut oak, scattering scrub black oak, scarlet oak, and huckleberry.
1450 feet.	Hill-top.	Steep bluff, Keokuk Limestone.	Scrub post oak, mountain chestnut oak, winged elm, redbud. spicewood, and azalea.

TABLE No. 8.

Barometric height.	Location.	Formation.	Timbers.
1575 ft. (N. W. F.)	Base of Muldraugh's Hill, on Rolling Fork.	Devonian Shale, with Corniferous, right in creek.	Mountain chestnut oak, beech, red oak. sour-wood, scrub white oak, and mountain maple.
1640 feet.	Hill-side.	Beginning of Keokuk Limestone.	Magnificent white oak. chestnut, liriodendron, black oak, black hickory, white hickory, ash, black locust, &c. (Note.—Great change in timbers in passing onto Keokuk.)
1675 feet.	Hill-side.	Keokuk Limestone.	Splendid liriodendron, chestnut, white and shag hickory, redbud, sugar maple, spicewood, and mulberry.
1700 feet.	Hill-side.	Keokuk Limestone.	Same as last. and black and blue ash, linden, black cherry, black walnut, hawthorn, red oak, and amelanchier.
1735 feet.	Hill-side.	Thin Waverly or upper Keokuk Shale.	Mountain chestnut oak, black oak, red oak, pig hickory, and iron-wood.
1810 feet.	Hill-top.	. . . .	Mountain chestnut oak, scrub black hickory, blue ash (one), small red oak, and azalea. (Note.—The breaking of our mercurial barometer prevented the preparation of further data until Irvine was reached.)

TABLE No. 9.

Barometric height.	Location.	Formation.	Timbers.
1290 feet. (N. F.)	Base of Estill Springs Knob.	Devonian Shale.	White oak, pin oak, black gum, and honey locust. No small growth.
1350 feet.	Hill-side.	Same, with detritus of Cortigalli Sandstone.	White oak, liriodendron, red oak, water beech, sour-wood, and pine (*mitis*).
1385 feet.	Bench.	Top of Devonian Shale.	On the Shale bench only pine, dwarf red oak, and post oak.
1420 feet.	Saddle of bench.	Cortigalli Sandstone.	White oak, Spanish oak, scarlet oak, white maple, huckleberry, and sour-wood.
1465 feet.	Hill-side.	Same.	Mountain chestnut oak, scarlet oak, white maple, huckelberry, and black sumach
1580 feet.	Same.	Same, with heavy detritus.	Very heavy undergrowth of hickory, black oak, redbud, and dogwood. Old trees are white oak and black oak.
1685 feet.	Same.	Cortigalli bluff.	Mountain chestnut oak, mountain maple, redbud, sour-wood, and dogwood.
1720 feet.	Same.	Cortigalli.	Mountain chestnut oak, shrub white hickory, winged elm, dogwood, &c.
1785 feet.	Hill-top.	Same.	Mountain oak, scrub hickory, scarlet oak, redbud, scrub elm, huckleberry, and pine (*mitis*). Pines and white sumach almost exclusively occupy the south face of the Knob.

TABLE No. 10.

Barometric height.	Location.	Formation.	Timbers.
1300 feet.	Base of "Winding Stairs," 14 miles from Irvine.	Keokuk Limestone.	Swamp chestnut oak, white oak, white and shag hickory, liriodendron, black ash, rich red oak, sycamore, box-elder, red elm, buckeye, sugar maple, American linden, magnolias (cucumber and Frazeri), mulberry, sweet gum, red birch, and catalpa.
1480 feet.	Hill-side—base of bluff.	Base of St. Louis Limestone.	Up to this bluff, last timbers flourish. Fine belt of linden at this height.
1535 feet.	Bench of hill.	St. Louis Limestone.	All foot-hill timbers are found on this bench, as it is the *spring level*, and the ground is very moist Spicewood and willow are also found.
1575 feet.	Bench of hill.	Base of Chester Sandstone.	Splendid chestnut, white oak, liriodendron, white and pig hickory, umbrella tree, black and blue ash, water beech, dogwood, &c. (NOTE.—Appearance of chestnut on Sandstone)
1700 feet.	Bench of hill.	Base of Conglomerate Sandstone.	Chestnut, liriodendron, black beech, white hickory, linden, black gum, water beech, mountain chestnut oak, and dogwood.
1750 feet.	Hill-side.	Conglomerate Sandstone.	Chestnut, mountain maple, mountain chestnut oak, black gum, water beech, dogwood, rhododendron, and azalea.
1800 feet.	Hill-side.	Same.	Thicket of Kalmia (latifolia), rhododendron (max.), with chestnut oak, mountain maple, water beech, sour-wood, huckleberry, amelanchier, and azalea.
1820 feet.	Hill side.	Same.	Pine begins. Other timbers same as last.
1900 feet.	Hill-top.	Same.	Pine, scarlet oak, scrub black oak, dogwood, sour-wood, black sumach, sassafras, and huckleberry.

TABLE No. 11.

Barometric height.	Location.	Formation.	Timbers.
1460 feet.	Base of characteristic low hill, six miles from Beattyville.	Conglomerate Sandstone, with underlying Shale.	Splendid white oak, liriodendron, black hickory, black ash, rich red oak, water beech, redbud, red maple, and dogwood.
1490 feet.	Hill-side.	Conglomerate Sandstone.	Belt of white hickory. Other timbers unchanged, except black ash and rich red oak have given out.
1520 feet.	Hill-side.	Same.	Spanish oak, black oak, black hickory, scrub white hickory, and scattering white oaks.
1545 feet.	Hill-top.	Same.	Spanish oak, scarlet oak, sour-wood, and dogwood.

TABLE No. 12.

1405 feet. (N. F.)	Base of hill, fifteen miles from Jackson.	Coal-measure Sandstone.	White oak, beech, chestnut, white maple, dogwood, black oak, red oak, and amelanchier.
1470 feet.	Bench of hill.	Same.	Splendid white oak, beech, water beech, hickory, green cornel, and black gum.
1510 feet.	Hill-side.	Same.	White oak ends. Mountain chestnut oak, water beech, mountain maple, black gum, dogwood, amelanchier, and sassafras.
1605 feet.	Level hill-top.	Same.	White oak, red oak, water beech (what a misnomer!), sour-wood, dogwood, and amelanchier. (NOTE.—Reappearance of white oak on detritus of low, level hill-top.)

TABLE No. 13.

Barometric height.	Location.	Formation.	Timbers.
1600 feet.	Base of "Town Hill," one and three fourths mile from Jackson.	Coal-measures.	Liriodendron, white oak, white and shag hickory, linden, umbrella tree, water beech, red maple, redbud, beech, dogwood, sour-wood, and amelanchier.
1640 feet.	Hill-side.	Same.	Beeches end. Other timbers same.
1690 feet.	Hill-side.	Same.	Spanish oak, red oak, black oak, black hickory, pig hickory, and one or two white oaks.
1750 feet.	Hill-side.	Same.	Red oak, black oak, chestnut, mountain chestnut oak, black locust, black gum, scarlet oak, and pine (*rigida*).
1835 feet.	Hill-top.	Same.	Black oak, red oak, chestnut, mountain chestnut oak, mountain maple, sour-wood, dogwood, &c.

TABLE No. 14.

1530 ft. (N. W. F.)	Foot-hill on Troublesome Creek, twenty-one miles from Hazard.	Coal-measure Sandstone.	Sycamore, beech, linden, sugar maple, white elm, gray birch, big buckeye, papaw, liriodendron, rich red oak, amelanchier, golden Alexander, spicewood, magnolia (*Frazeri*), and dogwood.
1620 feet.	Dark, rich hill-side.	Same.	Nearly all beeches; some large liriodendron, blue ash, black gum, sugar maple, and small cornel.
1690 feet.	Same.	Same.	White oak, beeches, black gum, cornel bushes, and golden Alexander.
1740 feet.	Bench of hill.	Same.	White oak, white hickory, black gum, sugar maple, and beeches, the latter forming 80 per cent. of timbers.
1780 feet.	Hill-side.	Same.	Beeches (50 per cent.), chestnut, white oak, black gum, sour-wood, dogwood, huckleberry, and golden Alexander.
1840 feet.	Hill-side.	Same.	Chestnut, black birch, rock maple, beech, kalmia, sour-wood, and dogwood.
1875 feet.	Hill-side.	Same.	Chestnut, red oak, black oak, thin-bark hickory, mountain maple, mountain chestnut oak, sour-wood, and amalanchier.
1920 feet.	Rocky bluff.	Same.	Mountain chestnut oak, dwarf chestnut, rock maple, kalmia, amelanchier, and sour-wood.
1975 feet.	Hill-top.	Same.	Gray birch, mountain maple, and sour-wood.

TABLE No. 15.

Barometric height.	Location.	Formation.	TIMBERS.
1975 ft. (S. E. F.)	Opposite face of preceding hill—hill-top.	Coal-measure Sandstone.	Timbers last given.
1925 feet.	Hill-side.	Same.	Splendid pig hickory, black oak, black locust, red oak, mountain chestnut oak, mountain maple, and dogwood.
1900 feet.	Hill-side.	Same.	Liriodendron begins. Black walnut, linden, red mulberry, red oak, black oak, and gray birch.
1860 feet.	Hill-side.	Same.	Beeches begin. Mountain chestnut oak ends. In addition to beeches, sugar trees, liriodendron, and linden are found.
1775 feet.	Hill-side.	Same.	Splendid liriodendron, white oak, big buckeye, sugar trees, red oak, and gray birch.
1680 feet.	Hill-side.	Same.	Umbrella and beeches (the latter forming 90 per cent. of timbers).
1524 feet.	Foot-hill.	Same.	Same as foot-hill timbers on opposite side of hill.

TABLE No. 16.

1560 feet. (N. F.)	Foot-hill on Lost Creek, fourteen miles from Hazard.	Coal-measure Sandstone.	Hemlock, chestnut, red maple, white oak, water beech, beech, linden, black gum, gray birch, alder, spicewood, dogwood, sour-wood, and magnolia.
1605 feet.	Hill-side.	Same.	White oak, magnolia, water beech, white maple, black gum, gray birch, spicewood, and dogwood.
1655 feet.	Hill-side.	Same.	Linden, white oak, chestnut, gray birch, water beech, rock maple, red oak, amelanchier, sour-wood, and dogwood.
1705 feet.	Hill-side.	Same.	Splendid chestnut belt, pig hickory, black oak, black hickory, a few white oaks, gray birch, mountain chestnut oak, sour-wood, dogwood, and golden Alexander.
1760 feet.	Hill-side.	Same.	Chestnut, red oak, black gum, gray birch, black locust, mountain maple, mountain chestnut oak, and huckleberry.
1825 feet.	Bend of hill.	Same.	White oak (small amount), chestnut, black oak, mountain chestnut oak, beech, sour-wood, dogwood, sassafras, and amelanchier.
1925 feet.	Hill-top.	Same.	Red oak, black gum, thin-bark hickory, chestnut, and mountain chestnut oak.

TABLE No. 17.

Barometric height.	Location.	Formation.	TIMBERS.
1880 feet.	Base of hill, starting over from head waters of Lost to those of Lot's Creek, six miles from Hazard.	Coal-measures.	Splendid liriodendron, white oak, chestnut, beeches, black and blue ash, rich red oak, sugar maple, black birch, white and pig hickory, white maple, magnolia (umbrella, cucumber, and auriculata), hemlock, and dogwood.
2040 feet.	Top of divide—low gap.	Same.	Chestnut, liriodendron, white oak, white hickory, black and gray birch, black oak, black hickory, dogwood, and sour-wood.
2120 feet.	Hill-bench.	Same.	Red oak, black oak, black gum, mountain chestnut oak, pine (*rigida*), and kalmia.
2180 feet.	Hill-side.	Same.	Black-jack, scrub oak, and pine (*rigida*).
2225 feet.	Top of Sandstone bluff.	Same.	Pine (*mitis*), scrub black oak, and scrub red oak (*ilicifolia*).
2265 feet.	Hill-top.	Same.	Pine, scrub chestnut, and mountain chestnut oak.

TABLE No. 18.

Barometric height.	Location.	Formation.	TIMBERS.
1700 feet. (N. F.)	Base of rich hill, with three veins of coal, five miles from Hazard.	Coal-measures.	White oak, liriodendron. beeches (50 per cent. of timbers), linden, black ash, box-elder, swamp chestnut oak, white ash, white and black hickory, magnolia, white walnut, red oak, buckeye, water beech, papaw, and spicewood.
1825 feet.	Hill-side.	Same.	Splendid blue ash, white oak, liriodendron, shag hickory, gray birch, water beech, sugar maple, black gum, hazelnut, golden Alexander, and dogwood.
2020 feet.	Hill-side.	Same.	Liriodendron, chestnut, black oak, hickories, &c. Not much change from last timbers.
2220 feet.	Hill-side.	Same.	Magnificent forest of liriodendron, linden, black and blue ash, black hickory, black walnut (not large), sugar maple, birch, swamp chestnut oak, rich red oak, redbud, spicewood, papaw, and dogwood.
2300 feet.	Base of bluff.	Same.	Liriodendron, chestnut, linden, blue ash, rich red oak, black locust, dogwood.
2375 feet.	Hill-side.	Same.	Mountain chestnut oak, black oak, scrub white hickory, mountain maple, Amelanchier, dogwood, sour-wood, and huckleberry.
2425 feet.	Hill-side.	Same.	Pine (*rigida*), huckleberry, and Kalmia.
2500 feet.	Hill-top.	Same.	Pine (*rigida*), red oak, mountain maple, huckleberry, and kalmia.

TABLE No. 19.

Barometric height.	Location.	Formation.	TIMBERS.
1920 ft. (S. S. W. F.)	Base of divide between Breeding's Creek and Rockhouse Creek, thirteen miles from Whitesburg.	Coal-measures.	Beeches, white oak, liriodendron, white and black walnut, big buckeye, rich red oak, linden, water beech, magnolia, winged and red elm, black ash, white hickory, willows, dogwood, and sour-wood.
1980 feet.	Hill-side.	Coal-measures.	Beeches, gray birch, liriodendron, black gum, linden, buckeye, white walnut, magnolia, and dogwood.
2050 feet.	Same, near head of branch under brow of hill.	Coal-measures.	Magnificent liriodendron, blue ash, white hickory, shag hickory, chestnut, sugar maple, beeches, mulberry, rich red oak, buckeye, water beech, dogwood, and papaw.
2180 feet.	Hill-side.	Coal-measures.	Belt of white oak, with black oak, chestnut, hickory, magnolia, dogwood, amelanchier, sour-wood, and sassafras.
2250 feet.	Hill-side.	Coal-measures.	Chestnut, black locust, iron-wood, rock maple, black gum, amelanchier, sour-wood, and dogwood.
2290 feet.	Broken Sandstone bluff.	Coal-measures.	Mountain chestnut oak, chestnut, kalmia, dogwood, and sour-wood.
2340 feet.	Top of bluff.	Coal-measures.	Mostly pines (*rigida and mitis*), since last level. Here, chestnut, scrub white hickory, black oak, rock maple, scrub post oak, black sumach, amelanchier, sour-wood, and dogwood.
2355 feet.	Hill-side.	Same—shaly Sandstone.	Thicket of post oaks, with scrub white hickory, mountain ash, black locust, and mountain chestnut oak.
2400 feet.	Base of bluff.	Massive Sandstone.	Only mountain chestnut oak trees, with small growth same as at 2340 level.
2500 feet.	Hill-top.	Coal-measures.	Chestnut, mountain chestnut oak, black locust, scrub red and black oak, scrub hickory, dogwood, and sassafras.

TABLE No. 20.

Barometric height.	Location.	Formation.	Timbers.
2120 feet.	Base of divide, between Kolley's Branch and Sandy Lick, seven miles from Whitesburg.	Coal-measures.	Splendid white oak, liriodendron, white hickory, beeches, black gum, sugar maple, big buckeye, linden, black ash, mulberry, rich red oak, gray birch, magnolia (cucumber), and papaw.
2250 feet.	Hill-side.	Same.	Chestnut, red maple, rock maple, beeches, sour-wood, dogwood, and sassafras. (I was unable to go higher on this hill. The top would be about 2400 feet.)

TABLE No. 21.

Barometric height.	Location.	Formation.	Timbers.
2230 feet.	Base of Pine Mountain, starting through Pound Gap.	Coal-measures.	White oak, liriodendron, linden (American and Canadian), chestnut, rich red oak, hemlock, beeches, magnolias, black and blue ash, gray and black birch, red maple, black gum, buckeye, dogwood, and sour-wood.
2475 feet.	Mountain-side, one mile from Pound Gap.	Line of Pine Mountain fault. Devonian Shale.	Mountain chestnut oak, chestnut, beech, gray birch, scrub oak, red oak, magnolia, mountain maple, white walnut, shag hickory, liriodendron, white oak, black gum, linden, and wintergreen. (NOTE.—We pass almost immediately from Devonian Shale onto Keokuk, and there is little perceptible change in the timbers.)
2560 feet.	Mountain-side.	Keokuk Limestone.	Magnificent liriodendron, chestnut, linden, ashes, buckeye, rich red oak, white hickory, black walnut; some white oak, sugar trees, black locust, black birch, magnolia, mountain chestnut oak, water beech, and papaw.
2700 feet.	Mountain-side.	Saint Louis Limestone.	Linden, white hickory, liriodendron, pig hickory, red oak, buckeye, black locust, gray birch, and mountain chestnut oak. (NOTE.—Absence of chestnut.)
2800 feet.	Mountain-side.	Chester Sandstone.	Chestnut, white walnut, linden, black oak, sugar trees, shellbark hickory, and mountain chestnut oak.
2870 feet.	Bluff.	Same.	Mountain chestnut oak, mountain maple, magnolia, gray and spotted birch, black locust, scrub oak, scrub chestnut, rhododendron and kalmia, dogwood, and sour-wood.

2925 feet.	Mountain-side.	Very micaceous Sandstone. Conglomerate (?)	Chestnut, mountain chestnut oak, black and blue ash (not large), black locust, linden, mountain maple, magnolia, and white walnut.
3100 feet.	Pound Gap—top of divide.	Conglomerate Sandstone.	Chestnut, red oak, black locust, white walnut, mountain chestnut oak, pith elder, white and black sumach, sassafras, dogwood, and sour-wood.
3260 feet.	Peak to right of gap, going south.	Conglomerate.	Small shell-bark hickory, chestnut, mountain chestnut oak, scrub oak, spotted birch, dwarf black hickory, mountain hazelnut, huckleberry, and sassafras.
3410 feet.	Top of peak.	Same.	Shell-bark hickory, mountain chestnut oak, gray birch, linden (small), black locust, white walnut, black oak, scrub oak, scrub white oak (only one), chestnut, spotted birch, sassafras, and sour-wood. (NOTE.—On the opposite (southeast) face of the mountain there is a great deal of pine, but no other material difference in the timbers.)

From the foregoing tables, taken from different parts of the forests throughout the entire length of the State, and, therefore, as general as it is possible to obtain them, much information can be obtained as to the effect of height above drainage on Kentucky timbers. For instance, let us take white oak and go through the various tables. The following is the result:

Timbers.	Height of hill in feet.	Height to which white oak grows.	Proportion of height to which white oak grows to entire height of hill.	Formation.
White oak . .	135	40	30—	Silicious Limestone.
White oak . .	185	130	70+	Silicious Limestone.
White oak . .	163	75	46+	St. Louis Limestone.
White oak . .	173	68	35+	St. Louis Limestone.
White oak . .	150	150	100	Keokuk Limestone.
White oak . .	600	275	46+	Keokuk Limestone.
White oak . .	330	130	39+	Cincinnati Limestone.
White oak . .	235	100	43—	Devonian Shale and Candigalli.
White oak . .	435	230	53—	Candigalli.
White oak . .	85	60	71—	Conglomerate Sandstone.
White oak . .	135	135	100	Coal-measures.
White oak . .	235	90	38+	Coal-measures.
White oak . .	445	250	56+	Coal-measures.
White oak . .	401	251	63—	Coal-measures.
White oak . .	365	265	73—	Coal-measures.
White oak . .	385	150	40+	Coal-measures.
White oak . .	800	520	65	Coal-measures.
White oak . .	580	260	45—	Coal-measures.
White oak . .	1030	336	32+	Coal-measures.

From this table can readily be deduced the average height of all the hills in Kentucky selected for these experiments, the average height above drainage to which white oak grows, and the relation that the latter height bears to the entire height of the hill. The following table shows these deductions:

Timbers.	Average height of hill.	Average height on hill to which white oak grows.	Proportion of latter to former.
White oak	308.8	184.7	60 nearly.

In other words, throughout the forests of Kentucky the white oak extends, on a general average, over sixty per cent. of the

hills. A slight examination will also show that on Keokuk limestone white oak extends to seventy-three per cent. of the total height of the hills; on Conglomerate sandstone, to seventy-one per cent.; on coal-measures, to fifty-seven per cent.; on silicious limestone, to fifty per cent.; and on St. Louis limestone, to forty per cent. This indicates that Keokuk, leaving out the Keokuk shales, is the richest of the formations in white oak growth.

In the same way it may be shown, from the general tables, that liriodendron extends to an average of forty-five per cent. of the total heights of hills, or not quite half way. The reader can easily make deductions for all other timbers. It will be noticed that there is no general and definite relation existing between the height of hills and the height to which any particular timber will grow. Everything depends upon the nature of the hill, and upon whether the formation is adapted to retaining moisture. On a damp hill, though very high, a timber will be found, growing entirely to the top, which would not extend more than a few feet up another and drier hill. It is exceedingly interesting, though, to know the *average* height above drainage to which the principal forest trees extend; and that can be deduced from the tables given.

SUMMARY.

A brief review of the foregoing pages will show—

First. That changes in geological formation will produce immediate, and often exceedingly marked, effects upon the character of the timbers. Such changes are often noticed, in *shallow-rooted* timbers, before a change of formation is reached, owing to the effect of detritus from the neighboring formation. They may likewise be noticed in very *deep-rooted* timbers, for the opposite reason, that their roots extend down beneath the surface formation, and penetrate the underlying one, when that is not visible.

Second. That height above drainage always produces a marked effect upon timbers, whatever the formation; but that such effect is less in the case of a Keokuk limestone formation than in any other found in Kentucky.

Third. That there is no regular proportion between the total heights of hills and the heights to which particular timbers grow. Everything depends upon the nature of the formation.

Fourth. That of the marked difference in character between the forests of Eastern and those of Western Kentucky, only the distribution of the pines can be satisfactorily accounted for without further and special study in that direction.

LIST OF TIMBERS.

The following is a list of timbers met with and spoken of in this Report:

ORDER CUPULIFERÆ—MASTWORTS.

1. *Genus Quercus—oak.*
   - White oak, Quercus alba (L.)
   - Swamp white oak, Q. bicolor (Willd.)
   - Bartram oak, Q. heterophylla (Mx.)
   - Red oak, Q. rubra (L.)
   - Spanish oak, Q. falcata (L.)
   - Scarlet oak, Q. coccinea (Wang.)
   - Post oak, Q. obtusiloba (Mx.)
   - Rich red oak, Q. macrocarpa (Mx.)
   - Black oak, Q. tinctoria (Bart.)
   - Pin oak, Q. palustris (Mx.)
   - Laurel oak, Q. imbricaria (Mx.)
   - Swamp laurel oak, Q. laurifolia (Mx.)
   - Chestnut oak, Q. castanea (Muhl.)
   - Swamp chestnut oak, Q. prinus (Willd.)
   - Chinquapin oak, Q. prinoides (Willd.)
   - Black-jack, Q. nigra (L.)
   - Scrub oak, Q. ilicifolia (Willd.)
2. *Genus Castanea—chestnut.*
   - Common Chestnut, Castanea vesca (L.)
   - Chinquapin, Castanea pumila (Mx.)
3. *Genus Fagus—beech.*
   - Common beech, Fagus sylvatica (L.)
   - Red variety, Fagus ferruginea (Ait.)

4. *Genus Corylus—hazelnut.*
   - Common hazelnut, Corylus Americana (Walt.)
5. *Genus Ostrya—hop hornbeam.*
   - Common ironwood, Ostrya Virginica (Willd.)
   - Var. hornbeam, Carpinus Americana (L.)
   - (NOTE.—I prefer giving the latter as a mere variety of the former, rather than as a distinct *genus carpinus.*)

ORDER JUGLANDACEÆ.

1. *Genus Carya—hickory.*
   - Black hickory, Carya tomentosa (Nutt.)
   - White hickory, Carya microcarpa (Nutt.)
   - Shag hickory, Carya alba (Nutt.)
   - Shellbark hickory, Carya sulcata (Nutt.)
   - Pig hickory, Carya glabra (Torr.)
2. *Genus Juglans—walnut.*
   - Black walnut, Juglans nigra (L.)
   - White walnut, Juglans cinerea (L.)

ORDER BETULACEÆ.

1. *Genus Betula—birch.*
   - Black birch, Betula lenta (L.)
   - Red birch, Betula nigra (Ait.)
   - Yellow birch, Betula excelsa (Ait.)
   - Spotted birch, Betula pumila (L.)
2. *Genus Alnus—alder.*
   - Swamp alder, Alnus serrulata (Willd.)

ORDER ACERACEÆ.

1. *Genus Acer—maple.*
   - White maple, Acer dasycarpum (Ehr.)
   - Black maple, Acer nigrum (Mx.)
   - Red maple, Acer rubrum (L.)
   - Same, Var. tridens.
   - Sugar maple, Acer saccharinum (L.)
   - Mountain maple, Acer spicatum (Lam.)
2. *Genus Negundo.*
   - Box-elder, Negundo aceroides (Moench)

ORDER CONIFERÆ.

1. *Genus Pinus—pine.*
Yellow pine, Pinus mitis (Mx.)
Pitch pine, Pinus rigida (Miller.)
Loblolly pine, Pinus taeda (L.)
White pine, Pinus strobus (L.)
Mountain pine, Pinus pungens (Mx.)

2. *Genus Abies.*
Hemlock, Abies canadensis (Mx.)

3. *Genus Taxodium.*
Bald cypress, Taxodium distychum (Rich.)

4. *Genus Juniperus.*
Common cedar, Juniperus Virginiana.

ORDER ULMACEÆ.

1. *Genus Ulmus—elm.*
Red elm, Ulmus fulva (L.)
Winged elm, Ulmus alata (Mx.)
Cork elm, Ulmus racemosa (Thomas.)
White elm, Ulmus Americana (L.)

2. *Genus Celtis.*
Hackberry, Celtis occidentalis (L.)

ORDER ROSACEÆ.

1. *Genus Cerasus—cherry.*
Black cherry, Cerasus serotina (D. C.)

2. *Genus Prinus—plum.*
Common plum, Prinus Americana (Marsh.)

3. *Genus Cratægus—thorn.*
Black thorn, Cratægus tomentosa (L.)
Yellow thorn, Cratægus punctata (Jacq.)
Hawthorn, Cratægus oxycantha (L.)

4. *Genus Amelanchier.*
Service berry, Amelanchier canadensis (T. & G.)
Same, shrub, Var. oblongifolia (T. & G.)

5. *Genus Spiræ.*
Ninebark, Spiræ opulifolia (L.)
Mountain spiræ, Spiræ corymbosa (Raf.)

ORDER OLEACEÆ.

1. *Genus Fraxinus—ash.*
Black ash, Fraxinus sambucifolia (Lam.)
Blue ash, Fraxinus quadrangulata (Mx.)
White ash, Fraxinus Americana (L.)
Green ash, Fraxinus viridis (Mx.)

ORDER MAGNOLIACEÆ.

1. *Genus Magnolia.*
Big laurel, Magnolia grandiflora (L.)
Cucumber tree, Magnolia acuminata (L.)
Umbrella tree, Magnolia umbrella (Lam.)
Big-leafed magnolia, Magnolia macrophylla (Mx.)
Ear-shaped magnolia, Magnolia Fraseri (Walt.)

2. *Genus Liriodendron.*
Tulip tree (yellow poplar), Liriodendron tulipfera (L.)

ORDER TILIACEÆ.

1. *Genus Tilia—linden tree.*
American basswood, Tilia Americana (L.)
Canadian or white basswood, Tilia heterophylla.
Canadian or white basswood, Var. alba (Vent.)

ORDER ERICACEÆ.

1. *Genus Kalmia.*
Spoon-wood, Kalmia latifolia (L.)

2. *Genus Gaultheria.*
Wintergreen, Gaultheria procumbens (L.)

3. *Genus Vaccinium.*
Blueberry, Vaccinium corymbosum (L.)

4. *Genus Oxydendrum.*
Sorrel tree, Oxydendrum arboreum (D. C.)

5. *Genus Azalea.*
White azalea, Azalea viscosa (L.)
Pinxter-bloom, Azalea nudiflora (L.)
Tree azalea, Azalea arborescens (Ph.)

6. *Genus Rhododendron.*
   Large rhododendron, Rhododendron maximum (L.)
7. *Genus Clethra.*
   Sweet pepper, Clethra alnifolia (L.)

ORDER SALICACEÆ.

1. *Genus Populus.*
   Cotton tree, Populus Angulata (Ait.)
   Aspen, Populus tremuloides (Mx.)
   Balm of Gilead, Populus candicans (Ait.)
   Silver-leafed poplar, Populus alba (L.)

ORDER LEGUMINOSÆ.

1. *Genus Gymnocladus.*
   Coffee tree, Gymnocladus canadensis (Lam.)
2. *Genus Gleditschia.*
   Honey locust, Gleditschia triacanthus (L.)
3. *Genus Robinia.*
   Black locust, Robinia pseudacacia (L.)
4. *Genus Cercis.*
   Redbud, Cercis canadensis (L.)
5. *Genus Cladastris.*
   Yellow wood, Cladastris tinctoria (Raf.)

ORDER CORNACEÆ.

1. *Genus Nyssa.*
   Black gum, Nyssa multiflora (Wang.)
   Swamp black gum, Nyssa uniflora (Wang.)
2. *Genus Cornus.*
   Common dogwood, Cornus florida (L.)
   Yellow dogwood, Cornus sericea (L.)
   Green cornel, Cornus alternifolia (L.)

ORDER SAPINDACEÆ.

1. *Genus Æsculus.*
   Big buckeye, Æsculus flava (Ait.)
   Small buckeye, Æsculus pavia (L.)

ORDER HAMAMELACEÆ.

1. *Genus Liquidamber.*
   Sweet gum, Liquidamber styraciflua (L.)
1. *Genus Hamamelis.*
   Witch hazel, Hamamelis Virginiana (L.)

ORDER ANACARDIACEÆ.

1. *Genus Rhus—sumach.*
   Smooth sumach, Rhus glabra (L.)
   Large sumach, Rhus typhina (L.)
   Mountain sumach, Rhus copallina (L.)
   Poison oak (sumach), Rhus toxicodendron (L.)

ORDER AQUIFOLIACEÆ.

1. *Genus Ilex.*
   Holly, Ilex opaca (L).

ORDER CAPRIFOLIACEÆ.

1. *Genus Sambucus.*
   Pith elder, Sambucus canadensis (L.)
2. *Genus Liburnum.*
   Black haw, Liburnum prunifolium (L.)

ORDER ARTOCARPACEÆ.

1. *Genus Morus.*
   Red mulberry, Morus rubra (L.)

ORDER PLATANACEÆ.

1. *Genus Platanus.*
   Sycamore, Platanus occidentalis (L.)

ORDER RUTACEÆ.

1. *Genus Xanthoxylum.*
   Prickly ash, Xanthoxylum Americanum (Miller.)
2. *Genus Ailanthus.*
   Tree of heaven, Ailanthus glandulosa (Desf.)

ORDER BIGNONIACEÆ.

1. *Genus Catalpa.*
   Catalpa, Catalpa bignonioides (Walt.)

ORDER LAURACEÆ.

1. *Genus Benzoin.*
Spicewood, Benzoin odoriferum (Nees.)

2. *Genus Sassafras.*
Common sassafras, Sassafras officinale (Nees.)

ORDER ANONACEÆ.

1. *Genus Asimina.*
Papaw, Asimina triloba (Dunal.)
Same, Asimina parviflora(?) (Dunal.)

ORDER CALYCANTHACEÆ.

1. *Genus Calycanthus.*
Sweet shrub, Calycanthus floridus (L.)

ORDER EBENACEÆ.

1. *Genus Diospyros.*
Persimmon, Diospyros Virginiana (L.)

ORDER CELASTRACEÆ.

1. *Genus Enonymus.*
Burning bush, Enonymus Americanus (L.)

ORDER UMBELLIFERÆ.

1. *Genus Thaspium.*
Golden Alexander, Thaspium cordatum (Nutt.)

ORDER CAMELLIACEÆ.

1. *Genus Stuartia.*
Stuartia, Stuartia Virginica (Cav.)

GEOLOGICAL SURVEY OF KENTUCKY.

N. S. SHALER, Director.

REPORT

ON THE

TIMBERS OF BOYLE AND MERCER COUNTIES.

BY W. M. LINNEY.

Part XI. Vol. V. Second Series.

STEREOTYPED FOR THE SURVEY BY MAJOR, JOHNSTON & BARRETT, YEOMAN PRESS, FRANKFORT, KY.

INTRODUCTORY LETTER.

Prof. N. S. Shaler, *Director of the Kentucky Geological Survey*.

Dear Sir: In pursuance of instructions from the Office of the Survey, I have for some time past been making a study of the timbers of Boyle and Mercer counties. I herewith submit the results of my investigations, which, though not as complete and elaborate as could be desired, will, I hope, be found as full and correct as could be expected for the limited time given for the work.

My thanks are due to a number of persons for information given, and I take this opportunity to return them.

Respectfully,

W. M. LINNEY.

Harrodsburg, Ky., July, 1879.

REPORT ON THE TIMBERS OF BOYLE AND MERCER COUNTIES.

GENERAL REMARKS.

The district comprising the counties of Boyle and Mercer is very interesting from the point of view of its botany and its geology.

As these sciences are so intimately connected in some particulars, I have thought it best, in the following report, to refer briefly to its geological features, and endeavor, at the same time, to show some of those well-marked peculiarities in the distribution of certain vegetable species, largely due to the variations and conditions of the soils.

Though this question may not be viewed in itself as an economic element in the present supply of timbers in this region, yet the distribution and adaptation of certain species to soils will become of great economic importance for the future, when the propagation and cultivation of valuable trees shall be forced upon posterity, either from necessity or for profit.

This district was one of the first portions of the State to become settled; and as, for more than a hundred years, there has been a continual increase in the population, it necessarily follows that there has been a continual and increasing demand made upon its forests.

Resulting from this drain, about sixty per cent. of the surface has been entirely denuded of its native trees, and over the remainder a large proportion of its valuable timbers have been removed.

The destruction of late years has been very great; and, if continued in the same ratio, it will not be long before the last tree shall have passed away.

A recently published item in one of the local newspapers asserted, that of the woods remaining in Boyle county, seventy-five per cent. had been destroyed in ten years.

From my own knowledge of the county during that period, and careful observations made during the year, I am satisfied that, in some sections, the statement is no exaggeration; but the proportion is evidently too large for the whole county.

In Mercer, the destruction has not been so great, yet it has been large enough to seriously alarm those whose attention has been called to the subject.

In the first settlement of the country, a great deal of valuable timber was undoubtedly destroyed in clearing the lands for cultivation; but years have passed since any of the forests were thus removed.

Some logs have been cut near the Kentucky river, and floated to market, and some lumber has been shipped out of Boyle county by railroad; but the quantity has been comparatively small.

It follows then, as a general rule, that the forests have been felled, and their material used in the district: the cherry and walnut for furniture, the poplar (liriodendron), oak, ash, and chestnut for buildings; these, and other varieties, for fences and fire-wood, and the bark from the chestnut oak for tanning.

At the present time nearly all of the lumber used in house-building and furniture is either imported from the North, or from the mountain counties of the State.

A number of small saw-mills are still at work in various parts of those counties, cutting up the remnant of available and marketable trees.

Perhaps the greater part of the denudation may be viewed as legitimate; but much of it should have been avoided, and no excuse can be offered for the destruction, wanton sometimes, carried on, save ignorance and cupidity.

From all the evidences, I am satisfied that, originally, no part of Kentucky had a fairer property in the size, variety, and quality of its forest trees, or in the beauty and richness of its general flora.

While over a greater portion of its surface the native plants are gone, yet crowded back into the slopes and hollows of the knobs, and the steep cliffs of the rivers, with here and there a thicket, are many plants whose occurrence is rare; and in comparing the incomplete list, appended to this report, with the flora of other districts, and with the knowledge that this is on the geologic summit of the State, I have reached the conclusion that this section has been one of the centers from which the plant life of surrounding portions of the country has been distributed.

GEOLOGY AND TIMBER DISTRIBUTION.

From the deep gorges of the Kentucky and Dick's rivers to the top of the knobs in the southern part of Boyle county, there is exposed about fifteen hundred feet of rock sections, extending from the Kentucky river series, the probable equivalent of the Trenton period, up to, and including, the waste of the Millstone Grit.

These various series of rock masses, from which the soils are immediately derived, have given quite a number of soils that differ very materially from one another.

This dissimilarity is due usually to the chemical character of the various layers, which, added to the qualities derived from their depth, drainage, elevation, and exposure, seem to be the controlling causes that have produced the diversity observed in the distribution of a number of the species of plants.

To those who have not investigated the causes, the location of various belts of different trees growing in this district is remarkable. Some of them I will briefly notice:

THE TRENTON AREA.

Nearly all of the region from a line southwest of Danville, and extending between Salt river on the west to Dick's and Kentucky rivers on the east, and north nearly through Mercer county, as well as a strip extending from Salt river west nearly through Boyle county, is based on the Trenton Limestones.

Through the first mentioned portion, there evidently once flowed a stream, which in time became a swamp of some depth, and considerable dimensions, but which had, at the time of the first settlement of the county, been divided by underground drainage into several portions which were still marshy in their character.

The timber was largely made up of those species that love a wet location.

Blue ash (*Fraxinus quadrangulata*) grew everywhere in this belt, and in greater numbers than any other species.

The chinquapin oak (*Quercus castanea*) almost rivaled it in numbers and distribution.

The sycamore (*Platanus occidentalis*) grew at some points in plenty, and of magnificent size.

The buckeye, especially the Ohio buckeye (*Aesculus glabra*), was very common.

Wild cherry (*Cerasus serotina*) was here in considerable quantities; while the hickory, black walnut (*Juglans nigra*), black oak (*Quercus nigra*), and hackberry (*Celtis occidentalis*) were common. Among these grew many other species, with an undergrowth of grape-vines, spice-wood, and cane. White oak, birch, and poplar (liriodendron) were notably absent. Surrounding this swampy tract, but based on the same limestones, is a higher region, with better drainage and drier soils. On these soils there was a considerable change in species. Sycamore ceased; blue ash, chinquapin oak, overcup oak, and wild cherry decreased, while white oak, black walnut, sugar maple, and others, increased in numbers.

A few beeches were scattered here and there, and where the geodes and pebbles of the higher rocks were preserved in beds, a few poplars grew.

The red cedar everywhere covered the rocky walls of the river cliffs, and dogwood, along with cane, gave variety to the undergrowth.

LOWER BEDS OF CINCINNATI GROUP.

The lower beds of the Cincinnati Group, extending from their base to the silicious mudstone, occupy the area between

Chaplin and Salt rivers, in Mercer county, and also a belt, extending east and west, through Boyle county, south of the Trenton exposure.

The beds here consist of brown and blue shales, with intercallated beds of thin limestones.

These limestones have been much shattered, so that everywhere the roots of trees could penetrate to a great depth.

That this is necessary for the white oak (*Quercus alba*), I am not prepared to say; yet this is the most remarkable white oak region that I have ever seen. The forest might be said to be almost entirely of that species. Very often it is ten to one of all other trees. Some red oak is found, and where there are good east and west exposures, and a deep coating of leaf mold, some clumps of sugar maple occur; few other trees are seen, and many of those found on the Trenton are noticeably absent.

The size and quality of this white oak was very fine, and although the destruction has been great, the timber of this kind, in the region between the rivers named, is by far the most valuable within the two counties. The prices of white oak I found to be from one to eight dollars per tree, according to size and location.

Its principal use is for fencing purposes, though many valuable trees are cut every year for fire-wood alone.

The farms over this area, where the land has been cleared a few seasons, are usually covered with stones. These stones, if removed and put into permanent fences, would add value to the land, and save in the cutting of timber; but the rule is to leave them on the fields as they lie, or to pile them up over the ground. Farmers lose the use of the soil thus covered, while the same labor would almost suffice to put them in a fence; and this is done by persons who have to purchase timber for their rails, or buy the rails made to hand.

I am disposed to think that the average amount of the white oak over this belt was equal to, if not greater than, seventy-five per cent.

From a number of counts I made over widely-separated localities, where the woods had been little disturbed, I computed the following table:

SPECIES.	Per cent.
White oak	78
Red oak	5
White ash	3
Sugar maple	4
Hickory	4
Other species	6
	100

Undergrowth, dogwood and some others.

On the lowest beds that contained no shale were notably a few post oaks and laurel oaks. I noticed one peculiar characteristic of the post oak (*Quercus obtusiloba*), which I have not seen mentioned: that is, its tops are never erect. I have examined a great many trees, and every one was leaning in some direction from a perpendicular.

I have not seen a single point where any protection has been given to secure a reproduction of oak timber. The supply is not much greater than would be required to replace the inclosures were they destroyed; so it seems that not a generation must pass ere the white oak must be "numbered with the things that were."

SILICIOUS MUDSTONE.

The middle division of the Cincinnati Group here consists of one hundred or more feet of exposed shales, that extend east and west nearly through Boyle county, and form the surface soil on Deep creek, in the western part of Mercer.

With the exception of a few harder layers, it disintegrates very rapidly, and, to a considerable depth, leaving a very loose half sandy soil. This soil, after clearing, needs great care to maintain its fertility.

The surface lies in short, steep, rounded hills, and where the soil or sod is broken, it is rapidly worn into gullies, often many feet in depth.

These soils produced beech as its most abundant growth; but the walnut and poplar trees occurring on it could not well be surpassed, the latter sometimes eight or nine feet in diameter. Some sugar maple, white oak, and white ash were also found, yet the species were few compared to some other soils.

THE UPPER BEDS OF THE CINCINNATI GROUP.

The outcrop of these, from their steep dip beneath the knobs, in an east and west line through Boyle county, gives but a narrow exposure, and their surface on each side of the little anticlinal, through which the North Rolling Fork flows, is also small. The timber, as a general rule, has all been cut off, and I found it impossible to make out a table that would exhibit the distribution over its surface.

Sugar maple, walnut, poplar, and white oak seem to have been the leading species, with quite a mixture of other kinds. The same remarks will apply equally as well to the exposure of the Corniferous, except that the waste of its cherty member is scattered over much of the lower series, and thus produced more variety in the forests that once covered it.

THE OHIO SHALE (BLACK SLATE).*

This formation, where unmixed with the decomposed rocks of the upper series, is inferior for agricultural purposes, yet it has given a fine forest of beech. Its outcrop is everywhere marked by this timber, which, in many places, is the only growth.

Where it is disposed to be marshy, there is sweet gum, swamp white oak, and some other trees, and where the Waverly shale has covered the slopes, chestnut is often found.

THE WAVERLY.

The greater mass of the knobs in Boyle county is composed of the Waverly shale, and holds the larger part of the remaining timbers of the county.

From the various conditions of soil here found, there is a

*This is the Huron shale of many geologists; but it has been termed Ohio shale in these Reports to avoid the risk of confounding it with the "Huronian."—N. S. S.

great variety of species; but in their distribution there is a certain order.

The tops of the knobs, where the shale covers the surface, is well marked by the New Jersey scrub pine (*Pinus inops*), rock chestnut oak (*Quercus prinus var monticola*), and chestnut, with such shrubs as sumac, huckleberry, service berry, and others. Along the streams sycamore, sugar maple, white maple, and walnut, together with other kinds, grow.

Where the leaf mold is deep, and the waste of Sub-carboniferous limestone has added its richness, and the direction of the exposures give variety, almost every species peculiar to the district may be found; but everywhere the best trees are rapidly decreasing, and in many spots all the kinds are being destroyed.

THE SUB-CARBONIFEROUS LIMESTONES.

This series of rocks is found only on a small portion of the knobs. Where it extends up to the decomposed rocks of the St. Louis Group, it gives a soil of fair character, which, as it lies in a small synclinal, is better protected than is usual in this section. Its principal growth seemed to have been white oak, red oak, and black oak.

A few patches of the wasted sands and pebbles from the Millstone Grit have retained the characteristic cucumber tree (*Magnolia accuminata*).

DESTRUCTION OF SOILS.

Trenton.—The exposures of the Trenton soils are comparatively level, save on the steeps near the rivers; and as their drainage is commonly underground through fractures, caves, and sink-holes, the soil is not so liable to be washed away during heavy rains; consequently, the destruction of the soils has not been great, except in limited areas.

In some places the massive layers of the bird's-eye limestone have been uncovered, and the area become worthless. This stone is so little acted upon by atmospheric and other causes, that it must require ages to reproduce a soil over it.

Along the bluffs of the Kentucky and Dick's rivers are many places that can never be cultivated, but which have been covered with timber. These, with care, would still produce trees. Yet these have been and are being cleared in such a manner that the little soil, exposed to the beating rains and the more rapid freezing and thawing, is being washed off to the bare rock.

Lower Cincinnati.—Were it not for the great preponderance of shales or marlites that this series contains, among the solid limestone layers, the soils derived from them would hardly, from the usage to which they are subjected, last five years over the greater part of its area.

Over thousands of acres of land that have been cleared for some time, it seems, from an examination of the few trees left in fields, that often, for a depth of several feet, the soil has been entirely washed away; but such is its power and fitness for a speedy conversion into soils, that every turning by the plow leaves it as rich in plant-food as before. The lower layers, notably those full of heavy beds of branching corals, have, however, a different character, and over those beds a large per cent. of the soils have been ruined.

Silicious Mudstone.—The soils on this group, from their soft character and the steepness of their slopes, wear away very fast when cleared and under cultivation. A slight break in the soil or sod starts a wash that, unless stopped in its incipiency, will soon gully down many feet. So rapid is this destruction, that only a few years is necessary to render whole fields worthless. Wanting usually in lime and cohesive properties, it is hard to restore these slopes to fertility; so the ruin has been great.

Ohio Shale.—The soils derived exclusively from the Ohio shales are, as a general rule, poor for agricultural purposes.*

Being thin, their destruction is rapid after clearing. The surface exposure is not large, yet much of this has been injured by the removal of the forests.

* This inferiority is principally due to their impervious nature; when well underdrained, they are nearly as fertile as the blue limestone soils.—N. S. S.

Waverly Shales.—This group of shales is left only as slopes, often of considerable steepness, with here and there belts on the top that are comparatively level over small areas. Those level points have been cleared to some extent, and where put in fruit trees, promise something for the future; but where under cultivation, as soon as the leaf mold is exhausted, their value is lost.

This soil will not produce blue-grass; and when it has been uncovered down to the shale, it seems to be impossible to form soil over it again. Its character is well illustrated at Knob Lick, near Danville Junction. This point, perhaps, contains a hundred acres, and about one hundred feet of those shales are here exposed. Bare of all vegetation, save a few lichens and mosses, the soil all gone, and the shales gullied down through the whole thickness, it is a miniature desert, and a striking illustration of what the Kentucky knobs are to become when they have been entirely denuded of vegetable coverings.

Hundreds of these licks now exist, and every year adds to their number. It required ages to clothe them with plants, and this only with the aid of the fertilizers from the other series of rocks. A few years, under the influences now going on, will leave them bare.

The complete destruction of the timber over this area will be fraught with ill effects other than the destruction of the soils. (See below.)

The cause of the rapid destruction of these shales seems to be two-fold. Containing little except clay, water entering their crevices dissolves them, or freezing separates the particles, thus allowing them to be wasted rapidly.

The other reason is due to the quantities of iron pyrites which they contain. This substance is speedily decomposed when exposed to the air or water. The iron, sulphur, and alum in their combinations being injurious to plants, the shales are left in a finely divided state on the surface, and are swiftly washed away.

These knobs should never be cleared, and as the old trees

are removed, the young ones should be encouraged and protected. They should be left intact, for all time to come, as nurseries from whence the local timber wants must be supplied, otherwise the whole extension of the Waverly will be but one vast Knob Lick.

Bottom Lands.—In Mercer county there are no bottom lands of much extent, and in Boyle county the only ones of note are situated on the North Rolling Fork. By clearing away the fringe of timbers on the margin of this stream, and from the more sudden rising of the floods than formerly, a great deal of valuable land has been swept away, and each year sees an additional amount crumbling into the stream to be carried away. Proper care would have prevented this in the past, and might save yet much for the future.

REPRODUCTION OF TIMBERS.

Perhaps more than half of the surface of these two counties, remaining in woodlands, is totally devoid of young trees of any description. Should they come up, and the cattle not kill them, they are carefully grubbed out of the way.

The knobs contain much young timber. Some of the white oak woods abound in small trees, and over the other sections are left an occasional thicket where the young growth is thick.

A few walnuts have been left in some places. These walnut trees promise little—growing isolated, and oftenest in the sunlight, they become stinted, with forking heads and many branches.

The honey-locust (*Gleditschia triacanthos*) gives the most forcible illustration of this law of any species that have come under my observation. The original trees of this species are fine, tall trees, without thorns, and the young trees in the undisturbed woods are unarmed; but wherever growing over the county, in isolated conditions, they are low, bushy, and covered from root to branch with horrid thorns.

Trees, to grow tall and straight, and fit for lumber, must be close enough to have their lower limbs shaded. These limbs drop off in time, and, as the individuals run up, they acquire long trunks. This seems to be the only condition necessary to give valuable timber.

As a rule, the poorer species are everywhere coming to the front, and succeeding the valuable kinds. As far as I have been enabled to investigate this fact, it is not due, unless exceptionally, to any change in the soil or climate, but depends upon the preservation and distribution of the seed.

Perhaps the more common species to take possession of the soil are honey-locust, black locust, coffee-bean, and red-bud. The seed from these trees are protected by such hard coverings that they are preserved for many years in the ground. Year by year they make their appearance as young trees. It is probable that they may lie in the ground for many years, and only germinate when favorable conditions arise.

The seeds of the wild cherry, hackberry, cedar, and the haws are widely scattered by birds, and germinate wherever they may fall. While elm, box-elder, and other kinds, have their fruit widely disseminated by the winds, and are among the first to propagate themselves. Of the more valuable kinds, their seed often do not last longer than one season, and then may be entirely destroyed.

The white oak has few chances for reproduction. The woods are everywhere a range for hogs, and with the birds and squirrels to help them, the acorns are all eaten, and I found it impossible in the spring to find a single specimen during a careful search.* Yet where hogs have been kept from inclosed woodlands, it is no unusual thing to see hundreds of young white oaks under a single parent tree. Black oak, laurel oak, and post oak having more bitter fruit, the acorns are not so much sought after; consequently, they have more chances in the race for life, and young trees are oftener found. I can see no reason to prevent the valuable species from taking and keeping the lead, if only a little care be exercised in the preservation of their seed, and in the destruction of the poorer kinds of plants.

*See on this point the successive Reports of Mr. L. H. DeFriese, in the 2d, 4th, and 5th volumes of this series of Reports.—N. S S.

For some purposes the red cedar (*Juniperis Virginiana*) is a truly valuable species. Over all the limestone soils, where the rocks are near the surface, it is increasing in great numbers, and does well on rocks so bare that few other kinds can find a footing with it. Reason would suggest its preservation. For fences and posts no wood is more enduring. Last winter I saw some stock successfully wintered in a cedar thicket. If the wide-spread destruction of timber over the United States is continued a few years longer, the erection of great stables and sheds will be too costly for small farmers, and I know of no better substitute that can be devised than groves of cedar.

The worn-out farm-lands, if put in trees, in time would be good again. Started as nurseries of valuable species, each year's growth would add value, both to soil and plants, and, in a near future, they might be of more pecuniary value than all the rest of the farm.

Every farm in this district, however small, should have a grove, where young trees, of the best species suited to the soil, should have the same careful attention given them that any other growing crop receives.

The cutting away of woods over this district should cease, and no greater proportion of cleared lands to forests should ever exist. All the valuable trees of this region could be raised nearly everywhere, and the sooner their cultivation is begun, the more will posterity have to thank us for our wisdom. The care and expense given in the past to such introduced species as catalpa, balm of gilead, white poplar, lombardy poplar, ailanthus, and others, would have produced thousands of the most valuable trees, with no loss to the beauty of home or country.

OTHER DESTRUCTIVE EFFECTS.

In a region of unbroken forests the streams are usually clear, and their flow is comparatively regular. The piles of leaves, the beds of moss, and the deep leaf mold are as myriads of sponges that absorb the falling rain, the roots of plants are so many pipes penetrating the earth, leading the water into reservoirs, from which the whole year they find their exit through springs, and thus keep up the normal currents of larger streams.

In the first settlement of this district every hollow between the hills afforded a rill; springs burst forth everywhere along them, and every mile or so little branches flowed where the fish could hide. Stock found water on every farm. With the destruction of the forests thousands of these springs have been destroyed, and the rills have disappeared. The ruins of the "old mill" are seen by the side of a stony gulch, and passers-by wonder "where they got their water."

The atmosphere has increased in dryness, and the ill effects from protracted dry spells are far worse than formerly. Every old person, with whom I talked, asserted that the summers are more oppressive, and the crops more uncertain than formerly, and that these evils had increased from year to year.

Local rains during the summer are far more variable of late years, and it is no unusual thing to see clouds divide, and follow the greater belts of forests with refreshing showers, while the intervening region, almost treeless, is left without its supply. The greatest amount of rain over this district undoubtedly falls over the knob region, as there is the greatest and richest body of forests; and the fact is so patent that it has been noticed and discussed by many persons.

The heads of all the streams are located there, and, in a large measure, they are the reservoirs from which the springs and wells are supplied. The utter destruction of these forests would be a great calamity, and one from which the district could never recover. The streams of Knob Lick, Clark's Run, Salt river, and Chaplin would cease to flow, save after heavy rains, while the freshets would become much more destructive.

The elevation and geological structure of the district make these evils greater than in other sections of the State, and every effort should be made to prevent their increase in the future.

Added to the destruction of our timbers, as noted by human agency, is another element that is alarming in itself. *The remaining trees in our forests are dying*, not singly or in clumps, but over the whole country there seems to be universal decay. Over the more rolling parts of Boyle and Mercer one may travel mile after mile, and scarcely find a perfect tree.

The elms (*Ulmus Americana*) are dying outright, and the mortality among them seems to increase year after year. For some years past the dying trees have amounted to ten per cent. of their numbers, and during this summer several of our most observing owners of woodlands have estimated their loss as high as twenty per cent. I have examined a number of trees of this species, and find that the leaves are all punctured and galled by some insect, until it seems that they have lost the power to perform their necessary functions.

The oaks, particularly the white, red, laurel, and post oaks, are dying at the top. Everywhere, above the green foliage, the dead limbs protrude, and each season adds to their number and length. Growing trees require in a season an immense quantity of water, and if a sufficient amount is not furnished, the parts farthest from the roots suffer first. The blue-grass sod absorbs a large amount of moisture, so that in seasons of great drought little of the water falling on the surface penetrates beneath the rootlets of the sod. The top limbs die from thirst, and succeeding rains enter the rotten limbs, and work downward until the whole tree becomes involved.

Other species are differently affected; but all, in some form, and to a greater or less extent, have incipient decay written on them. One great cause seems to be, that in the large destruction of timbers, the proportion of insects to trees has increased, and their destructive effects largely developed.

From some observations made this year, together with the recollections of some years since, there seems to have been a decided increase in the quantity of the false mistletoe (*Phoradendron flavescens*) which infests our trees. May it not be that this plant is injurious to the trees upon which it grows? As this species has its habitat upon many of our most valuable species of timber trees, it is hoped that other and closer investigations will be made in regard to its influence.

SUMMARY.

The result of my observations and investigations may be summed up as follows:

First. That comparatively little really valuable timber remains in the district; the remainder seems doomed to speedy destruction, while no effort is being made to reproduce or protect young forests for the future.

Second. That a great deal of land has been ruined, or badly injured, by the destruction of the timber over it, and an unwise system of cultivation.

Third. That from the large destruction of forests, and its geological elevation, the atmosphere has become drier, crops more uncertain, and the water supply less.

Fourth. That the present proportion of cleared lands to forests should never be increased; but that, when suitable land should hereafter be cleared, an equal amount of injured soils should be given to the growth of forests.

Fifth. That no part of the knobs in Boyle county should ever be cleared entirely of trees; but every encouragement should be given to increase the forests upon them.

CONCLUSION.

Several interesting questions suggested themselves to my mind while preparing my notes. One I shall briefly notice, as it is a question the solution of which would be of considerable interest. Up to eight or ten years ago malarial diseases were little known over Boyle and Mercer counties; but they have, since that time, been gradually increasing.

In view of the reputed properties of the eucalyptus, may not a similar office have been performed by our native plants in the past, the destruction of which have left the way clear for this introduction of disease?

The subjoined list will be found nearly complete for the trees and shrubs; but for the smaller plants, owing to the

period of the year when the list was made, it does not show, perhaps, more than one fourth of the forms.

In the old deeds recorded in Mercer county, the Kentucky coffee-tree is named mahogany.

The common names for the aromatic sumac (*Rhus aromatica*) are stink-wood, polecat-wood, and skunk-wood, while the alder buckthorn (*Frangula caroliniana*) is called the Indian cherry. *Ptelea trifoliata* is known as the wafer-ash, and *Cladrastis tinctoria* is called shittim-wood.

The lead plant (*Amorpha canescens*) has its range in the West and Northwest, and is believed by miners to indicate the presence of lead ore. It seemed singular to find it growing here, out of its known district, and especially where some little lead is found in the veins of the deeper rocks that line the Kentucky river.

Perhaps we have no forest tree in this country of a more limited distribution than yellow-wood (*Cladrastis tinctoria*). It was quite common for some miles along the Kentucky and Dick's rivers, but has been nearly exterminated. Some measures should be taken to insure its preservation, not only on account of its beauty as an ornamental species, but its wood is really beautiful, and susceptible of a very fine polish, and for fancy work, where a yellow wood of great toughness is desirable, its value should be great. Some years since the Shakers gathered its seeds in large quantities, and sold them to nurserymen in the North; but I have been unable to learn the success that attended their efforts to propagate them.

The white pine (*Pinus Strobus*, L.) seems well adapted to some of our soils, growing rapidly and straight, shedding its lower limbs well, and would prove valuable for wind-breaks, and, in time, for timber.

Ranunculaceæ—

Leather flower, Clematis Viorna (L.)
Common virgin's bower, C. Virginiana (L.)
Carolina anemone, Anemone Caroliniana (Walt.)
Wind-flower, A. nemorosa (L.)

Round-lobed hepatica, Hepatica triloba (Chaix.)
Sharp-lobed hepatica, H. acutiloba (DC.)
Rue anemone, Thalictrum anemonoides (Mx.)
Tall meadow-rue, T. Cornuti (L.)
Early meadow-rue, T. dioicum (L.)
White water-crowfoot, Ranunculus aquatilis (L.)
Small-flowered crowfoot, R. abortivus (L.)
Hooked crowfoot, R. recurvatus (Poir.)
Bristly crowfoot, R. Pennsylvanicus (L.)
Early crowfoot, R. fascicularis (Muhl.)
Tall crowfoot, R. acris (L.)
Columbine, Aquilegia Canadensis (L.)
Tall larkspur, Delphinium exaltatum (Ait.)
Dwarf larkspur, D. tricorne (Mx.)
Azure larkspur, D. azureum (Mx.)
Field larkspur, D. consolida (L.)
Yellow-root, Hydrastis Canadensis (L.)
Red baneberry, Actæa spicata (L.), var. rubra (Mx.)
American bugbane, Cimifuga Americana (Mx.)

Magnoliaceæ—
Cucumber tree, Magnolia acuminata (L.)
Tulip tree, Yellow poplar, Liriodendron Tulipifera (L.)

Anonaceæ—
Papaw, Asimina triloba (Dunal.)

Menispermaceæ—
Canadian moonseed, Menispermum Canadense (L.)

Berberidaceæ—
Twin leaf, Jeffersonia diphylla (Pers.)
May-apple, Mandrake, Podophyllum peltatum (L.)

Papaveraceæ—
Celandine poppy, Stylophorum dyphyllum (Nutt.)
Puccoon, Blood-root, Sanguinaria Canadensis (L.)

Fumariaceæ—
Dutchman's breeches, Dicentra Cucullaria (DC.)
Squirrel corn, D. Canadensis (DC.)
Pale corydalis, Corydalis glauca (Pursh.)
Golden corydalis, C. aurea (Willd.)

Cruciferæ—
Water cress, Nasturtium sessiliflorum (Nutt.)
Marsh cress, N. palustre (DC.)
Toothwort, Dentaria diphylla (L.)
Bitter cress, Cardamine rhomboidea (DC.)
Rock cress, Arabis lyrata (L.)
Rock cress, A. patens (Sulliv.)
Rock cress, A. hesperidoides.
Black mustard, Sinapis nigra (L.)
Whitlow grass, Draba cuneifolia (Nutt.)
Shepherd's purse, Capsella Bursa-pastoris (Mœnch.)
Pepper-grass, Lepidium Virginicum (L.)

Violaceæ—
Green violet, Solea concolor (Ging.)
Round-leaved violet, Viola rotundifolia (Mx.)
Sweet white violet, V. blanda (Willd.)
Common blue violet, V. cucullata (Ait.)
Bird-foot violet, V. pedata (L.)
Long-spurred violet, V. rostrata (Pursh.)
Pale violet, V. striata (Ait.)
Canada violet, V. Canadensis (L.)
Downy yellow violet, V. pubescens (Ait.)
Pansy, V. tricolor (L.)

Hypericaceæ—
St. John's wort, Hypericum dolabriforme (Vent.)
St. John's wort, H. corymbosum (Muhl.)

Caryophyllaceæ—
Bouncing Bet, Saponaria officinalis (L.)
Starry campion, Silene stellata (Ait.)
Wild pink, S. Pennsylvanica (Mx.)
Fire pink, S. Virginica (L.)
Round-leaved catchfly, S. rotundifolia (Nutt.)
Cockle, Lychnis Githago (Lam.)
Sandwort, Arenaria patula (Mx.)
Common chickweed, Stellaria media (Smith.)
Great chickweed, S. pubera (Mx.)

Long-leaved chickweed, S. longifolia (Muhl.)
Larger mouse-eared chickweed, Cerastium vicosum (L.)

Portulacaceæ—
Purslane, Portulaca oleracea (L.)
Spring beauty, Claytonia Virginica (L.)

Malvaceæ—
Common mallow, Malva rotundifolia (L.)
Sida, Sida spinosa (L.)
Velvet leaf, Abutilon Avicennæ (Gærtn.)

Tiliaceæ—
Linden, basswood, Tilia Americana (L.)
White basswood, T. heterophylla (Vent.)

Linaceæ—
Wild flax, Linum Virginianum (L.)

Geraniaceæ—
Herb Robert, Geranium Robertianum (L.)
Pale touch-me-not, Impatiens pallida (Nutt.)
Spotted touch-me-not, I. fulva (Nutt.)
Common wood-sorrel, Oxalis Acetosella (L.)
Violet wood-sorrel, O. violacea (L.)
Yellow wood-sorrel, O. stricta (L.)

Rutaceæ—
Prickly ash, Zanthoxylum Americanum (Mill.)
Hop-tree, Ptelea trifoliata (L.)
Tree of Heaven, Ailanthus glandulosus (Desf.)

Anacardiaceæ—
Staghorn sumac, Rhus typhina (L.)
Smooth sumac, R. glabra (L.)
Dwarf sumac, R. copallina (L.)
Poison oak, R. Toxicodendron (L.)
Poison oak, var. radicans (L.)
Fragrant sumac, R. aromatica (Ait.)

Vitaceæ—
Summer grape, Vitis æstivalis (Mx.)
Winter grape, V. cordifolia (Mx.)

Fox grape, V. Labrusca (L.)
V. indivisa (Willd.)
Virginian creeper, Woodbine, Ampelopsis quinquefolia (Mx.)

Rhamnaceæ—
Buckthorn, Rhamnus lanceolatus (Pursh.)
Alder buckthorn, Frangula Caroliniana (Gray.)

Celastraceæ—
Climbing bitter-sweet, Celastrus scandens (L.)
Waahoo, Euonymus atropurpureus (Jacq.)
Strawberry bush, E. Americanus (L.)
Strawberry bush, var. obovatus (Torr & Gray.)

Sapindaceæ—
Bladder-nut, Staphylea trifolia (L.)
Ohio buckeye, Æsculus glabra (Willd.)
Sweet buckeye, A. flava (Ait.)
Red buckeye, A. pavia (L.)
Sugar maple, Acer saccharinum (Wang.)
Black sugar maple, A. nigrum (Mx.)
White maple, A. dasycarpum (Ehrhart).
Red maple, A. rubrum (L.)
Box-elder, Negundo aceroides (Mœnch.)

Polygalaceæ—
Milkwort, Polygala fastigiata (Nutt.)
Seneca Snakeroot, P. Senega (L.)

Leguminosæ—
Rabbit-foot clover, Trifolium arvense (L.)
Red clover, T. pratense (L.)
Zig-zag clover, T. medium (L.)
Buffalo clover, T. reflexum (L.)
White clover, T. repens (L.)
Low hop clover, T. procumbens (L.)
Sweet clover, Melilotus officinalis (Willd.)
White sweet clover, M. alba (Lam.)
Lead-plant, Amorpha canescens (Nutt.)
Locust tree, Robinia Pseudacacia (L.)

Wistaria, Wistaria frutescens (DC.)
Sensitive joint-vetch, Æschynomene hispida (Willd.)
Tick trefoil, Desmodium Canadense (DC.)
Tick trefoil, D. nudiflorum (DC.)
Vetch, Vicia Caroliniana (Walt.)
Spurred butterfly-pea, Centrosema Virginianum (Benth.)
Blue false indigo, Baptisia australis (R. Br.)
Yellow-wood, Cladrastis tinctoria (Raf.)
Redbud, Cercis Canadensis (L.)
Wild senna, Cassia Marilandica (L.)
Partridge pea, C. Chamæcrista (L.)
Wild sensitive plant, C. nictitans (L.)
Kentucky coffee-tree, Gymnocladus Canadensis (Lam.)
Honey-locust, Gleditschia triacanthos (L.)

Rosaceæ—

Wild plum, Prunus Americana (Marshall.)
Chickasaw plum, P. Chicasa (Mx.) (native.)
Wild cherry, Cerasus serotina (Ehrhart.)
Nine bark, Spiræa opulifolia (L.)
Agrimony, Agrimonia parviflora (Ait.)
Indian physic, Gillenia stipulacea (Nutt.)
Avens, Geum album (Gmelin.)
Five finger, Potentilla Canadensis (L.)
Five finger, var. simplex (Torr & Gray.)
Wild strawberry, Fragaria Virginiana (Ehrhart.)
Wild strawberry, F. vesca (L.)
Wild raspberry, Rubus occidentalis (L.)
Blackberry, R. villosus (Ait.)
Dewberry, R. Canadensis (L.)
Dwarf wild rose, Rosa lucida (Ehrhart.)
Sweet brier, R. rubiginosa (L.)
Washington thorn, Cratægus cordata (Ait.)
Red haw, thorn tree, C. coccinea (L.)
Black thorn, C. tomentosa (L.)
Cockspur thorn, C. Crus-galli (L.)

Crab-apple, Pyrus coronaria (L.)
Service-berry, Amelanchier Canadensis (Torr & Gray.)

Saxifragaceæ—

Wild gooseberry, Ribes Cynosbati (L.)
Wild hydrangea, Hydrangea arborescens (L.)
Early saxifrage, Saxifraga Virginiensis (Mx.)
Alum root, Heuchera caulescens (Pursh.)
Alum root, H. pubescens (Pursh.)
Bishop's cap, Mitella diphylla (L.)

Crassulaceæ—

Ditch stone-crop, Penthorum sedoides (L.)
Stone-crop, Sedum pulchellum (Mx.)
Stone-crop, S. ternatum (Mx.)

Hamamelaceæ—

Witch-hazel, Hamamelis Virginica (L.)
Sweet gum, Liquidamber Styraciflua (L.)

Onagraceæ—

Gaura filipes (Spach.)
G. biennis (L.)
Evening primrose, Œnothera biennis (L.)

Lythraceæ—

Clammy cuphea, Cuphea viscosissima (Jacq.)

Cactaceæ—

Prickly pear, Opuntia Rafinesquii (Engelm.)

Passifloraceæ—

Small passion flower, Passiflora lutea (L.)
Passion flower, P. Incarnata (L.)

Umbelliferæ—

Black snake-root, Sanicula Canadensis (L.)
Common carrot, Daucus Carota (L.)
Meadow parsnip, Thaspium aureum (Nutt.)
Smoother sweet cicely, Osmorrhiza longistylis (DC.)
Hairy sweet cicely, O. brevistylis (DC.)
Harbinger of spring, Erigenia bulbosa (Nutt.)

Araliaceæ—
Wild sarsaparilla, Aralia nudicaulis (L.)
Ginseng, A. quinquefolia (L.)

Cornaceæ—
Flowering dogwood, Cornus florida (L.)
Silky cornel, C. sericea (L.)
Rough-leaved dogwood, C. asperifolia (Mx.)
Alternate-leaved cornel, C. alternifolia (L.)
Black or sour gum, Nyssa multiflora (Wang.)

Caprifoliaceæ—
Buck-berry, Coral-berry, Symphoricarpus vulgaris (Mx.)
Small honeysuckle, Lonicera parviflora (Lam.)
Horse-gentian, Triosteum perfoliatum (L.)
Common elder, Sambucus Canadensis (L.)
Red-berried elder, S. pubens (Mx.)
Black haw, Viburnum prunifolium (L.)

Rubiaceæ—
Madder, Cleavers, Galium Aparine (L.)

Dipsaceæ—
Wild teasel, Dipsacus sylvestris (Mill.)

Compositæ—
Iron-weed, Vernonia Noveboracensis (Willd.)
Joe-Pye weed, Eupatorium purpureum (L.)
Horse-weed, Great ragweed, Ambrosia trifida (L.)
Ragweed, Hogweed, A. artemisiæfolia (L.)
Cocklebur, Xanthium strumarium (L).
Wild sunflower, Helianthus occidentalis (Riddell.)
Wild sunflower, H. grosse serratus (Martens.)
Wild sunflower, H. divaricatus (L.)
Common Beggar-ticks, Bidens frondosa (L.)
Swamp Beggar-ticks, B. connata (Muhl.)
Spanish needles, B. pinnata (L.)
May-weed, Maruta Cotula (DC.)
Common yarrow, Achillea Millefolium (L.)
Wormwood, Artemisia absinthium (L.)

Common everlasting, Gnaphalium polycephalum (Mx.)
Plantain-leaved everlasting, Antennaria plantaginifolia (Hook.)
Common thistle, Cirsium lanceolatum (Scop.)
High thistle, C. altissimum (Spreng.)
Burdock, Lappa officinalis (Allioni.)
Dandelion, Taraxacum Dens-leonis (Desf.)
Wild lettuce, Lactuca Canadensis (L.)
Sow thistle, Sonchus oleraceus (L.)

Lobeliaceæ—
Cardinal flower, Lobelia cardinalis (L.)
Indian tobacco, L. inflata (L.)

Campanulaceæ—
Tall bell flower, Campanula Americana (L.)

Ericaceæ—
Deerberry, Vaccinium stamineum (L.)
Dwarf blueberry, V. Pennsylvanicum (Lam.)
Sour-wood, Oxydendrum arboreum (DC.)
Laurel, Kalmia latifolia (L.)

Aquifoliaceæ—
American holly, Ilex opaca (Ait.)

Ebeneaceæ—
Persimmon, Diospyros Virginiana (L.)

Styracaceæ—
Storax, Styrax Americana (Lam.)

Plantaginaceæ—
Common plantain, Plantago major (L.)
Ribgrass, P. lanceolata (L.)
Ribgrass, P. pusilla (Nutt.)

Primulaceæ—
American cowslip, Dodecatheon Meadia (L.)
Loosestrife, Lysimachia ciliata (L.)
Loosestrife, L. lanceolata (Walt.)

Bignoniaceæ—
Cross vine, Bignonia capreolata (L.)
Trumpet creeper, Tecoma radicans (Juss.)

Catalpa, Catalpa bignonioides (Walt.)
Unicorn plant, Martynia proboscidea (Glox.)

Orobanchaceæ—

Beech-drops, Epiphegus Virginiana (Bart.)

Scrophulariaceæ—

Common mullein, Verbascum Thapsus (L.)
Moth mullein, V. Blattaria (L.)
Collinsia, Collinsia verna (Nutt.)
Beard-tongue, Pentstemon pubescens (Solander.)
Beard-tongue, P. Digitalis (Nutt.)
Thyme-leaved speedwell, Veronica serpyllifolia (L.)
Corn speedwell, V. arvensis (L.)
Water speedwell, V. Anagallis (L.)
Gerardia, Gerardia integrifolia (Gray.)

Acanthaceæ—

Ruellia ciliosa (Pursh.)

Verbenaceæ—

Narrow-leaved vervain, Verbena angustifolia (Mx.)
White vervain, V. urticifolia (L.)
Blue vervain, V. hastata (L.)
Fog-fruit, Lippia lanceolata (Mx.)

Labiatæ—

Spearmint, Mentha viridis (L.)
Peppermint, M. piperita (L.)
Wild mint, M. Canadensis (L.)
Common balm, Melissa officinalis (L.)
American pennyroyal, Hedeoma pulegioides (Pers.)
Lyre-leaved sage, Salvia lyrata (L.)
Wild bergamot, Monarda fistulosa (L.)
Horse-mint, M. punctata (L.)
Blephilia hirsuta (Benth.)
Giant hyssop, Lophanthus nepetoides (Benth.)
Catnip, Nepeta Cataria (L.)
Ground ivy, N. Glechoma (Benth.)
Synandra, Synandra grandiflora (Nutt.)
Self-heal, Brunella vulgaris (L.)

Skullcap, Scutellaria versicolor (Nutt.)
Skullcap, S. nervosa (Pursh.)
Serrate skullcap, S. serrata (Andrews.)
Mad-dog skullcap, S. lateriflora (L.)
Horehound, Marrubium vulgare (L.)
Motherwort, Leonurus Cardiaca (L.)
Dead nettle, Lamium amplexicaule (L.)

Borraginaceæ—

False gromwell, Onosmodium Carolinianum (DC.)
Gromwell, Lithospermum canescens (Lehm.)
Lungwort, Mertensia Virginica (DC.)
Stickseed, Echinospermum Lappula (Lehm.)
Hound's-tongue, Cynoglossum officinale (L.)
Wild comfrey, C. Virginicum (L.)
Beggar's lice, C. Morisoni (DC.)

Hydrophyllaceæ—

Waterleaf, Hydrophyllum macrophyllum (Nutt.)
Waterleaf, H. Virginicum (L.)
Waterleaf, H. Canadense (L.)
Waterleaf, H. appendiculatum (Mx.)
Phacelia, Phacelia bipinnatifida (Mx.)
Phacelia, P. Purshii (Buckley.)

Polemoniaceæ—

Greek valerian, Polemonium reptans (L.)
Phlox, Phlox paniculata (L.)
Phlox, P. Carolina (L.)
Phlox, P. divaricata (L.)
Ground or moss pink, P. subulata (L.)

Convolvulaceæ—

Morning-glory, Ipomœa purpurea (Lam.)
Morning-glory, I. Nil (Roth.)
Morning-glory, I. lacunosa (L.)
Wild potato vine, I. pandurata (Meyer.)
Bracted bindweed, Calystegia spithamæa (Pursh.)
Dodder, Cuscuta glomerata (Choisy.)

Solanaceæ—

Bittersweet, Solanum dulcamara (L.)
Common nightshade, S. nigrum (L.)
Horse nettle, S. Carolinense (L.)
Ground cherry, Physalis angulata (L.)
Ground cherry, P. pubescens (L.)
Ground cherry, P. viscosa (L.)
White Jamestown weed, Datura Stramonium (L.)
Purple Jamestown weed, D. Tatula (L.)

Gentianaceæ—

Columbo, Frasera Carolinensis (Walt.)

Loganiaceæ—

Polypremum procumbens (L.)

Apocynaceæ—

Dogbane, Apocynum androsæmifolium (L.)
Indian hemp, A. cannabinum (L.)

Asclepiadaceæ—

Common milkweed, Asclepias cornuti (Decaisne.)
Purple milkweed, A. purpurascens (L.)
Variegated milkweed, A. variegata (L.)
Four-leaved milkweed, A. quadrifolia (Jacq.)
Obtuse-leaved milkweed, A. obtusifolia (Mx.)
Swamp milkweed, A. incarnata (L.)
Green milkweed, Acerates paniculata (Decaisne.)
Green milkweed, A. viridifloræ (Ell.)
Gonolobus, Gonolobus obliquus (R. Br.)
Enslenia, Enslenia albida (Nutt.)

Oleaceæ—

White ash, Fraxinus Americana (L.)
Black ash, F. sambucifolia (Lam.)
Blue ash, F. quadrangulata (Mx.)

Aristolochiaceæ—

Wild ginger, Asarum Canadense (L.)

Phytolaccaceæ—

Pokewood, Phytolacca decandra (L.)

Chenopodiaceæ—

Lamb's quarters, Chenopodium album (L.)
Goosefoot, C. hybridum (L.)
Mexican tea, C. ambrosioides (L.)

Amarantaceæ—

Pig-weed, Amarantus retroflexus (L.)
Pig-weed, A. spinosus (L.)

Polygonaceæ—

Smart-weed, Polygonum hydropiper (L.)
Smart-weed, P. acre (H. B. K.)
Door-weed, P. aviculare (L.)
Black bind-weed, P. Convolvulus (L.)
Hedge bind-weed, P. dumetorum (L.)
Pale dock, Rumex Britannica (L.)
Curled dock, R. crispus (L.)
Bloody-veined dock, R. sanguineus (L.)
Sheep sorrel, R. Acetosella (L.)

Lauraceæ—

Sassafras, Sassafras officinale (Nees.)
Spicewood, Lindera Benzoin (Meisner.)
Spicewood, L. melissæfolia (Blume.)

Thymeleaceæ—

Leatherwood, Dirca palustris (L.)

Loranthaceæ—

American mistletoe, Phoradendron flavescens (Nutt.)

Euphorbiaceæ—

Spurge, Euphorbia corollata (L.)
Spurge, E. commutata (Engelm.)
Spurge, E. hypericifolia (L.)

Urticaceæ—

Slippery or red elm, Ulmus fulva (Mich.)
White elm, U. Americana (L.)
Corky white elm, U. racemosa (Thomas.)
Winged elm, U. alata (Mx.)
Planer tree, Planera aquatica (Gmel.)
Hackberry, Celtis occidentalis (L.)

Mulberry, Morus rubra (L.)
Wood nettle, Laportea Canadensis (Gaudichaud.)
Richweed, Pilea pumila (Gray.)
Wild hop, Humulus Lupulus (L.)

Plantanaceæ—

Sycamore, Platanus occidentalis (L.)

Juglandaceæ—

White walnut, Juglans cinerea (L.)
Black walnut, J. nigra (L.)
Pecan nut, Carya olivæformis (Nutt.)
Shellbark hickory, C. alba (Nutt.)
Small fruited hickory, C. microcarpa (Nutt.)
Western shellbark hickory, C. sulcata (Nutt.)
Mockernut hickory, C. tomentosa (Nutt.)
Pignut hickory, C. porcina (Nutt.)
Bitternut hickory, C. amara (Nutt.)

Cupiliferæ—

White oak, Quercus alba (L.)
Post oak, Q. obtusiloba (Mx.)
Burr oak, Q. macrocarpa (Mx.)
Chestnut oak, Q. Prinus (L.)
Rock chestnut oak, var. monticola (Mx.)
Yellow chestnut oak, var. acuminata (Mx.)
Laurel oak, Q. imbricaria (Mx.)
Black jack, Q. nigra (L.)
Scarlet oak, Q. coccinea (Wang.)
Red oak, Q. rubra (L.)
Chestnut, Castanea vesca (L.)
White beech, Fagus sylvatica (L.)
Red beech, F. ferruginea (Ait.)
Hazlenut, Corylus Americana (Walt.)
Ironwood, Ostrya Virginica (Willd.)
Water-beech, hornbeam, Carpinus Americana (Mx.)

Salicaceæ—

Glaucous willow, Salix discolor (Muhl.)
Petioled willow, S. petiolaris (Smith.)
Black willow, S. nigra (Marsh.)

American aspen, Populus tremuloides (Mx.)
Necklace poplar, P. monilifera (Ait.)
Balsam poplar, P. balsamifera, var. Candicans (L.)
White poplar, P. alba (L.), naturalized.

Coniferæ—

Jersey or scrub pine, Pinus inops (Ait.)
Red cedar, Juniperus Virginiana (L.)

Araceæ—

Indian turnip, Arisæma triphyllum (Torr.)
Dragon-root, A. Dracontium (Schott.)
Calamus, Acorus Calamus (L.)

Typhaceæ—

Cat-tail flag, Typha latifolia (L.)

Orchidaceæ—

Coral-root, Corallorhiza odontorhiza (Nutt.)

Amaryllidaceæ—

False aloe, Agave Virginica (L.)

Iridaceæ—

Blue flag, Iris versicolor (L.)
Dwarf iris, I. verna (L.)
Crested dwarf iris, I. cristata (Ait.)
Blackberry lily, Pardanthus Chinensis (Ker.)
Blue-eyed grass, Sisyrinchium Bermudiana (L.)

Dioscoreaceæ—

Wild-yam root, Dioscorea villosa (L.)

Smilaceæ—

Green briar, Smilax rotundifolia (L.)
Green briar, S. glauca (Walt.)
Green briar, S. tamnoides (L.)
Carrion-flower, S. herbacea (L.)

Liliaceæ—

Wake robin, Trillium sessile (L.)
Wake robin, T. recurvatum (Beck.)
Wake robin, T. erectum (L.)
Bell-flower, Uvularia perfoliata (L.)
Bell-flower, U. sessilifolia (L.)
Lily of the valley, Convallaria majalis (L.)

False Solomon's seal, Smilacina racemosa (Desf.)
Smaller Solomon's seal, Polygonatum biflorum (Ell.)
Greater Solomon's seal, P. giganteum (Dietrich.)
Dog's-tooth violet, Eythronium Americanum (Smith.)
Squill, wild hyacinth, Scilla Fraseri.
Wild onion, Allium cernuum (Roth.)

Filices—

Scaly polypody, Polypodium incanum (Swartz.)
Maiden-hair fern, Adiantum pedatum (L.)
Cliff-brake fern, Pellæa atropurpurea (Link.)
Ebony spleenwort, Asplenium ebeneum (Ait.)
Wall-rue spleenwort, A. Ruta-muraria (L.)
Narrow-leaved spleenwort, A. angustifolium (Mx.)
Marsh spleenwort, A. thelypteroides (Mx.)
Lady fern, A. Filix-fœmina (Bernh.)
Walking-leaf fern, Camptosorus rhizophyllus (Link.)
Beech fern, Phegopteris hexagonoptera (Fée.)
New York shield fern, Aspidium Noveboracense (Swartz.)
Marginal shield fern, A. marginale (Swartz.)
Christmas fern, A. acrostichoides (Swartz.)
Bulbous bladder fern, Cystopteris bulbifera (Bernh.)
Common bladder fern, C. fragilis (Bernh.)
Sensitive fern, Onoclea sensibilis (L.)
Obtused-leaved woodsia, Woodsia obtusa (Torr.)
Virginia moonwort, Botrychium Virginicum (Swartz.)
Ternate moonwort, B. ternatum (Willd.)

GEOLOGICAL SURVEY OF KENTUCKY.

N. S. SHALER, DIRECTOR.

REPORT

ON THE

CHINN'S BRANCH CANNEL COAL DISTRICT.

BY A. R. CRANDALL.

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REPORT ON THE CHINN'S BRANCH CANNEL COAL DISTRICT.

The Chinn's Branch and Indian Run Cannel Coal Region is one of a number of areas in Eastern Kentucky in which is found a cannel coal of workable thickness. As these cannel beds are not continuous over large areas, like the beds of common bituminous coal, it seems desirable to consider somewhat in detail those areas in which cannel coal is prominent, to call attention to them as suitable fields for business enterprise, and to furnish a ready means of comparison of the cannel coal regions when the work shall have been completed.

The Chinn's Branch district is most likely to receive early attention, from the fact that it is the most easily accessible of any of the cannel regions, though in extent it is much less than some others, and though the coal ranks second in quality to the deposits of some of the interior counties. It is the nearest coal region to be reached by the lower Ohio river trade, being but 130 miles from Cincinnati, and at the westernmost outcrop along the river of workable beds of coal. Indeed, it seems unaccountable that so little should have been done to develop this locality. It appears, however, that as early as 1859 the Maysville Manufacturing and Mining Company was formed to develop the cannel coal of what was known as the Caroline tract, including the greater part of the cannel coal area of this region, for the purpose of manufacturing illuminating oil. But the discovery of petroleum deposits in Pennsylvania operated to break up this enterprise; and what with the breaking out of the civil war, and the want of method since, the property has not been made profitable to the company.

An examination of the region shows that it occupies, geologically, that part of the vertical section which includes nearly all of the valuable beds, both of coal and of iron ore, of this eastern field. (See General Section, Report on the Geology of Greenup, Boyd, &c., Vol. II, New Series.) Some of these beds are too thin in this locality to be of any economic value at present. Coal No. 1, of the series above the conglomerate, is below the drainage, and though nothing is known of its value here, yet it may properly be left out of the list of workable beds, as also may Coal No. 2, which is too thin, where exposed, to interest any one except the geologist. Both beds are important in any comparison with other localities. The highest beds in this locality are the "Red Kidney" iron ore and Coal No. 7, the former near the top of the hills at the head of Chinn's Branch, in its ordinary relation to the latter, or separated from it by twenty to twenty-five feet of greenish shaly rock.

The cannel of this district is No. 4 of the series. The beds above and below are so well marked and so regular as to leave no doubt as to its place in the general section. Coal 4 is ordinarily a common bituminous bed. In this region this is replaced, wholly or in part, by cannel coal. The same is true of Coal No. 4 in the Hunnewell and the Stinson Creek regions. There are, however, other beds that exhibit local changes to cannel coal, and, considering this and the local character of the cannel coals, there would seem to be very little antecedent reason for supposing that the beds found at considerable intervals in the eastern coal field of Kentucky are also the equivalent of the Chinn's Branch and the Hunnewell deposits. The evidence at hand goes to show that in Morgan county the Pierat coal, and the upper cannel near West Liberty, and also the Breathitt county cannel, are the equivalent of the Chinn's Branch cannel seam, though the sections in the several localities differ very much as a whole; and further study of those regions may not sustain this conclusion.

The vertical section in the Chinn's Branch region differs in no very important respect from the typical section of Greenup, Boyd, and Carter counties already referred to, all the horizons of coal and of iron ore in that portion of the general section represented by the rocks of this region being well defined. The beds of economic value are of Coals 3, 4, and 7, with the possible addition of Coal 6, and of iron ores, the

limestone ore, and two kidney ores of the upper part of the section; the block ore near the horizon of Coal 4 being of little value, as is usual where that bed is prominent, either as cannel or a common bituminous coal.

Coal 3 is perhaps the most reliable bed in this region. It has an average thickness of about three feet, separated into two parts by about ten inches of clay shale or "draw-slate." It is overlaid by a few feet of shale, with thick sandstone above, and rests on the usual under-clay. This coal has not, until recently, come into favorable notice in this region, though the equivalent of this bed in Lawrence county, the Peach Orchard coal, has long been favorably known. By the enterprise of Mr. Bates, of the Eastern Kentucky Railway Company, this coal, as found in some parts of Greenup, has been shown to be a valuable bed, and on examination in the region in question, it is found that No. 3 is an exceptionally good coal, and that though it is not in great thickness, yet it is constant and easily mined. It is a splint coal, and bears transportation well, and is an exellent grate coal.

An analysis made for the Company by Dr. Peter shows the following, which may be regarded as an index of the quality of the coal:

Specific gravity	1.319
Moisture	5.00
Volatile combustible matter	39.00
Fixed carbon	49.88
Ash	6.12
Sulphur	1.986

The cannel coal of workable thickness appears to be limited in this region to an area oblong in outline, having its axis along a line from the old Fulton mines, near the landing, to a point on Indian Run, in the East Fork valley. How far beyond Indian Run, and how wide the area of cannel coal of workable thickness, has not been fully determined; but it may reasonably be estimated at from 1,500 to 2,000 acres. Several hundred acres of this area, belonging to the Fulton tract, have already been worked out, as also several narrow points in the valley of Chinn's Branch, on the Caroline tract;

but the great body of coal, covering a considerable portion of the latter tract, remains to be mined. The best information obtainable as to the thickness on the old Fulton tract gives it an average of about three feet. Further up, on Chinn's Branch, the bed has reached a thickness of four and a half feet. On Indian Run it is about two feet, but superior to the thicker part for gas-making. Like all cannel coals, it will probably be found variable in thickness and quality in the working of the bed. On the Indian Run the bed is accompanied by common bituminous coal, one foot on top and six to eight inches below, making the whole bed about the same in thickness as the average on Chinn's Branch, where the whole thickness is cannel.

In either case, the under-clay and the overlying rocks are essentially the same, and there are apparently no features on which more than a rough estimate of the quantity of cannel coal in this region could be based. A medium specific gravity would give about 1,500 tons, of 2,240 pounds to the acre, for each foot of thickness, or 4,500 tons for three feet, and 4,500,000 tons to the thousand acres. At the very smallest estimate, both as to the area and the thickness of the bed, the amount of cannel coal in this field, and lying within three to six miles of the Ohio river, is sufficient to warrant a systematic development of the territory, to say nothing of Coal 3, already described, and the coals above.

The only analyses of the cannel of this locality on record are two made for the Company by Dr. Peter, as follows:

	Chinn's Branch.	Indian Run.
Specific gravity	1.331	1.286
Moisture	4.80	2.00
Volatile combustible matter	36.90	47.36
Fixed carbon	51.20	38.24
Ash	7.10	12.40
Sulphur	3.977	1.554

Coal 6 has not been opened sufficiently to show its thickness and value. The evidence goes to show that it is present

at its proper level, 125 to 130 feet above Coal 4, probably over the whole region.

Coal 7, 45 feet higher up, has a thickness of three to three and one half feet of excellent coal, though the area is reduced to a comparatively small limit, the bed being near the top of the hill. This is the Coalton coal. In quality it is about the same as elsewhere. Entries have been driven, and a considerable amount of coal shipped from the ridge between Indian Run and Wolfpen Branch of Ash Creek. The two lower parts of the bed are uniformly present, separated by the usual thin parting. The upper part is said to be represented at some points by a few inches of coal, inferior in quality to the lower parts, as is usual with this bed elsewhere. The following measurements made at one entry agree substantially with those made at several others along the ridge:

	Feet.	Inches.
Overlying shaly rock, thickness not shown.		
Coal	2	
Slate parting		1
Coal	1	6
Under-clay, thickness not shown.		

The following analysis of an average sample from stock pile, together with that of the Coalton coal, as mined on Dry Branch by the Ashland Company, will serve to indicate the value of the bed, as to quality, in this region. (See remarks on the iron-making qualities of Coal 7, Part V, Vol. 1, New Series, Kentucky Reports.):

	COAL 7.	COAL 7.
	Head of Chinn's Branch.	Coalton, Dry Branch.
Specific gravity	1.324	1.340
Moisture	6.00	4.40
Volatile combustible matter	33.48	31.10
Fixed carbon	56.14	57.90
Ash	4.38	6.60
Sulphur	2.33	2.098

The iron ores of this locality are those of the Hanging Rock Region, including all the beds that are relied on for a supply of ore for the greater number of furnaces in this iron district. (For an intelligent account of these ores, see Mr. Moore's Report on the Iron Ores of Greenup, Carter, &c., Part III, Vol. 1, New Series, Reports on the Geology of Kentucky.)

The accompanying map will serve to give a more definite notion of the location of the cannel coal district in question. The dotted outline is only intended to give an approximate boundary, as sufficient work has not been done to make a definite boundary possible. The profile section gives a good notion of the place of the various beds of coal and of iron ore, in their relation to the drainage, and in their relation one to another.

APPENDIX.

The equivalency of the upper beds of the general section of Northeast Kentucky with those of Ohio is pretty well established. Coal 9, as shown opposite the mouth of Garner Creek, is the same as the Bagley's Run coal, or No. 7 of the Ohio report. Coal No. 8, Hatcher and Garner Creek, is also the Hatcher coal of Ohio, or No. 6B. No. 7, the Coalton seam, is in Ohio the Sheridan, the Nelsonville,* &c., or No. 6.

Coal 6, the Keyes Creek seam, is known in Ohio as the New Castle coal.

The ores and limestones associated with these coals are also readily recognized as equivalent beds; but below the horizon of the ferriferous limestone the correspondence with the beds of the Ohio section is not so clear, and, indeed, not so well defined as would be expected from the relation of the two fields, and from the comparatively slight variation from the typical section over a wide extent in Kentucky in the belt representing the lower part of the coal-measures. This is doubtless owing somewhat to the fact that the Ohio coal field has been more carefully studied in its northward extension, and that the general section is a better type of the geology northward than along the Ohio river.

It is probable that a general correspondence with the Kentucky beds exists for a considerable distance into Ohio, though less definite and probably more limited in its northward extension than that of the series above Coal 5. The Conway coal, No. 3C of Ohio, probably represents Coal No. 5 of Kentucky; and the Kelly coal, No. 3A, and the Wilbur coal, No. 3, may provisionally represent Coals 4 and 3 of Kentucky, the

* The Ohio Report of 1870 placed the Nelsonville seam immediately under the ferriferous limestone below Coal 6 of the Kentucky section; and in volume II, Report on the Geology of Greenup, Carter, &c., a thin coal, noted on Pea Ridge, at Pennsylvania Furnace, and at several points in the East Fork valley at this horizon, was spoken of as the equivalent of the Nelsonville coal. A subsequent visit to the Hocking valley made it clear that the Nelsonville and Straightsville coal seam occupies the place of the Coalton. The report of Professor Orton, of the Ohio Geological Survey, on the Geology of the Hanging Rock District (Vol. III), confirms this view.

Hunnewell or Chinn's Branch, and the Turkey Lick or Peach Orchard.

The place in our section of the Jackson shaft coal is a matter of considerable uncertainty. If, as is held in Volume III, Geology of the Hanging Rock District, this is an inter-conglomerate bed, then its probable equivalent in Kentucky is the Proctor coal of Lee county. If, as later observations seem to show, the conglomerate below this coal is a subcarboniferous deposit, and that above the true coal-measure conglomerate, then this coal is the probable equivalent of the Menifee coal, and of the thin bed found in Greenup and Carter below the conglomerate, when that is present, and closely associated with the great non plastic fire-clay bed of these counties. In either case, the Jackson Hill or the Wellston coal would be the same as No. 1 of the former Report on the Geology of Greenup, Carter, Boyd, and Lawrence.

If this view is correct, several thin beds, from two to four in number, between the Wellston and No. 3, the Wilbur of Ohio, would be set over against No. 2 and 2A of Kentucky. To this there is no special objection, since the additional beds are found at considerable distance from the Ohio river, and may be regarded as local beds.

GEOLOGICAL SURVEY OF KENTUCKY.

JOHN R. PROCTER, DIRECTOR.

CHEMICAL REPORT

OF THE

SOILS, COALS, ORES, CLAYS, MARLS, MINERAL WATERS, ROCKS, &C.,

OF KENTUCKY,

BY ROBERT PETER, M. D., ETC., ETC.,

CHEMIST TO THE SURVEY.

THE FOURTH REPORT IN THE NEW SERIES AND THE EIGHTH SINCE THE BEGINNING OF THE GEOLOGICAL SURVEY.

PART XIII. VOL. V. SECOND SERIES.

STEREOTYPED FOR THE SURVEY BY MAJOR, JOHNSTON & BARRETT, YEOMAN PRESS, FRANKFORT, KY.

INTRODUCTORY NOTE.

CHEMICAL LABORATORY OF KENTUCKY GEOLOGICAL SURVEY,
LEXINGTON, KY., June 10, 1879.

Prof. JOHN R. PROCTER, *Director of Kentucky Geological Survey:*

DEAR SIR: Herewith I respectfully submit to you the results of the chemical work performed in this Laboratory for the Geological Survey since the publication of my last report.

Yours, &c.,

ROBERT PETER.

CHEMICAL REPORT.

Of the one hundred and fifty-two new analyses reported on the following pages, there are of—

Soils, subsoils, and under-clays	90
Clays and marly clays and shales	25
Limestones	13
Waters	8
Iron ores	6
Coals	5
Silicious residues of soils	5

The soils examined show, as usual, a great variety of composition, as may be seen in the following table of their extremes of variation :

	(*a*) Pr. cent.	No.	County.	(*b*) Per cent.	No.	County.
Organic and volatile matters vary from . . .	9.305	in 2123	from Fulton .	to 1.840	in 2212	from M'Cr'k'n
Alumina and iron and manganese oxides vary from	14.368	in 2215	from Nelson .	to 2.932	in 2112	from Clinton.
Lime carbonate varies from.	2.485	in 2206	from Madison.	to .070	2212 and 2252	McCracken and Wayne
Magnesia varies from.	.989	in 2206	from Madison.	to .052	in 2221	from Pulaski.
Phosphoric acid varies from.	.387	in 2206	from Madison	to .029	in 2253	from Wayne.
Potash extracted by acids varies from	1.097	in 2154	from H'nd'rs'n	to .021	in 2253	from Wayne.
Soda extracted by acids varies from	.657	in 2215	from Nelson .	to traces	in sever	al.
Water expelled at 380° F. varies from	3.110	in 2123	from Fulton .	to .420	in 2153	from H'nd'rs'n
Sand and insoluble silicates vary from	76.715	in 2206	from Madison.	to 94.590	in 2253	from Wayne.
Water expelled at 212° F. varies from	4.104	in 2123	from Fulton . .	to .444	in 2253	from Wayne.
Potash in the insoluble silicates varies from. .	2.742	in 2215	from Nelson .	to .327	in 2112	from Clinton.
Soda in the insoluble silicates varies from . .	1.208	in 2099	from Ballard .	to .101	in 2110	from Clinton.
Gravel varies from.	None	in most	of these soils .	to 34.700	in 2220	from Pulaski.

Columns (*a*) and (*b*) give the chemical composition of very rich and very poor soils ; but being made up of extremes from the various soils, they do not represent the composition of any one of them. As may be seen by reference, these extremes are not quite so great as those reported in Volume IV and in the first part of this volume of these Reports.

Summing up all the soil analyses which have been made and reported, by the writer, for the Geological Survey of Kentucky, since its commencement in 1854, under the late David Dale Owen, M. D., to the present time, he finds them to number seven hundred and seventy-two; including soils, subsoils, and under-clays from eighty-seven counties of the State.

Of these, there were only one sample each from ten counties, two samples each from six counties, and three each from fifteen counties. From twenty-nine counties no samples of soils have as yet been collected. Of those reported in the following pages, nearly one half were collected in the year 1859, from the eastern coal field of our State, by Joseph Lesley, jr., then Geological Assistant in the Survey under Dr. Owen. These specimens of soils, having been carefully preserved in a dry place since the time of their collection, have remained unchanged, and their analyses are interesting, as proving that even in this sparsely settled mountainous region of Kentucky the soil is generally susceptible of profitable cultivation.

It is to be specially noted that, as the greater part of the soils of our State have been produced, in the localities in which they are found, by the disintegration of the superficial rock strata, and are not, like most of the soils of the great territory north and west of us, made up of mixed detritus which has been brought from other regions by the moving force of ice and water, the local character of our various soils is more dependent on that of their rock substrata than in the great territory in question. Hence we generally find our soils to be much richer lying on soft limestone or shaly rock strata than on the hard sandstones or conglomerates of the coal-measure formation Moreover, we find in some of the coal-measure soils a considerable proportion of angular gravel or fragments of soft ferruginous sandstone or sandy-ferruginous concretions; and in some the rounded quartzose pebbles of the mill-stone grit; while on the extended low plains, called in some parts of the State the "Barrens," because in former recent times they were destitute of trees, the smaller proportion or absence of gravel indicate formation of the soil under comparatively quiet water, by the wash of the finer earthy materials from the adjoining higher lands.

So far as our investigation has been carried, the soils of Kentucky, with the exception of some of those which lie on

the mountain slopes and valleys, especially in the coal-fields, are composed of materials in a state of very fine division; so fine, indeed, that the so-called "sand and insoluble silicates," left after the digestion of the soils in chlorohydric acid (specific gravity=1.1), will pass almost entirely through the fine sieve employed, which has 1,600 meshes to the centimeter square. Nowhere in the State have we found soils containing coarse sand, like some of those in the north or northwest of our continent. Hence, in the examination of our soils, "silt analysis," or the separation of the finer from their coarser materials, so useful when applied to some soils, has not been deemed of great importance, and has been seldom resorted to in the processes used.

This high state of comminution of our soils, by increasing the porosity and extent of surface of their materials, also increases their power of absorbing and retaining the fluid, dissolved solid, or the aeriform materials of plant-food, and greatly improves their fertility. Soils of this character could only be formed under quiet waters, or under water at a distance from its shores, or by the disintegration in place of rock strata which had been deposited under these conditions.

In the process of the analysis of these soils, they were digested for seven to ten days, on the sand bath, at a temperature below boiling, in five times their weight of chlorohydric acid, of specific gravity=1.1, a little nitric acid having been added to decompose the organic matters. In all of the soils reported in this, as well as in the two preceding Chemical Reports, the quantities of potash and soda which remained in the silicious residue, after digestion in these acids, was determined by a separate process, viz: that of ignition with a mixture of calcium carbonate and ammonium chloride, &c., according to the method of J. Lawrence Smith. These quantities, as may be observed by reference to the several analyses, are generally quite considerable.

On comparing the proportions of these two alkalies, severally, in the "sand and insoluble silicates" of the soils above mentioned, in number amounting to more than two hundred and fifty, we find their extremes to be as follows, calculated into the weight of the original soil:

The percentage of *potash* in the silicious residues varies from 2.910 per cent. in No. 2037, from Harlan county, to 0.327 per cent. in No. 2112, from Clinton county.

The percentage of *soda* varies from 1.208 per cent. in No. 2099, from Ballard county, to 0.018 per cent. in No. 1678, from Bell county.

The general composition of several of these silicious residues, as ascertained by complete analyses, by fusion with the alkaline carbonates, &c., is reported under the heads of Fulton and Nelson counties, to which the reader is referred for proof of the statement frequently made by the writer, that in this silicious skeleton of our soils a considerable proportion of silicates are found, which, while they may resist for a time the action of even moderately strong mineral acids, may yet, by a slow process of natural "weathering," measurably renovate the fertility of the soil from their reserved store of essential mineral elements of plant food.

In what form do these silicates exist in our soils, is a question of some interest. It has been known for some little time that silicates of the Zeolite group are found in soils, and that they perform a very important office in that selective, absorptive power which the soil possesses, by which it can withdraw from watery solutions, and hold for the benefit of growing vegetables, many essential elements of plant nourishment which else would be washed away in the drainage. Such silicates, no doubt, exist in our Kentucky soils; but they are known to be readily soluble in, or decomposable by, acids. It would seem probable, therefore, that the silicates, or the partly-weathered remains of silicates, in the silicious residue of our Kentucky soils, which had, to a certain extent, resisted the prolonged digestion in acids, were more of the nature of the minerals constituting the Feldspar group than the Zeolites.

As has been frequently stated in the reports, this silicious residue of our soils frequently left upon the fine sieve more or less of small particles, sometimes rounded, but often some-

what angular in form, which were generally soft enough to be crushed by the fingers into a powder fine enough to pass through the fine sieve. Until recently, the writer believed that these small particles represented, in their form at least, those silicates in the soil which had undergone a partial decomposition in the acid digestion, and which still retained, in their soft silicious skeletons, some of those alkalies which were found in the silicious residues.

But observing that the proportion of these residual soft particles did not bear any constant relation to that of the alkalies in the silicious residue, he was induced to examine, by washing with water, some of these soils, which left, after digestion in acids, the largest quantity of these so-called "partly decomposed silicates," and he was somewhat surprised to find that, in these soils at least, these soft particles were derived from little concretions in the soil, of the nature of so-called "shot iron ore," which probably had their origin in the infiltration of dissolved oxides of iron and manganese, or of calcium carbonate, or may have been originally oölitic aggregations in the rocks from whence the soils had been derived. Be this as it may, however, the important fact remains, that in the fine sandy or silicious residue of our soils, after prolonged digestion in acids, there exist potash, soda, lime, magnesia, and even a little phosphoric acid, which materials, although held in pretty firm combination as silicates in the insoluble residue, may prolong the productiveness of the soils under the slow decomposing action of the atmospheric agencies. Another fact is, that these silicates are in a state of as minute division in our soils as the fine silicious sand itself.

Of the eighteen new analyses of *Clays* herewith reported, fourteen are of clays from the tertiary formation, and one from the quaternary of the southwestern extremity of Kentucky, called the "Jackson Purchase." Three are from the Lower Silurian formation in Madison county.

The *tertiary deposits* of the first-mentioned region show considerable variety in their composition and properties. Some are highly silicious or sandy; some are quite calcareous; and others, containing more alumina, exhibit different varieties of clay, some being of the nature of good fire-clay. Those which contain a considerable proportion of silicious matter, some of which may be in the form of fine sand, and which contain but small quantities of iron oxide, lime, potash, or soda, deserve a trial as glass-pot clay, provided they are sufficiently plastic, or burn sufficiently hard. Others may be available as fire-clay for many other purposes, and several would answer well for the manufacture of different sorts of pottery-ware, terra-cotta, drain-tiles, bricks, &c., according to their nature.

Some of these beds, their material being in a finely-divided state and friable, might be made useful in the manufacture of artificial hydraulic cement, of the character of Portland cement, whenever such an industry may be profitable in this region. Some of these deposits are so highly quartzose that they could be employed in the manufacture of glass. The "loess" from the quaternary may be locally useful as a top-dressing on heavy clay soils, &c.

The *clays* reported from Madison county are too readily fusible to be used as fire-clays, yet are good plastic clays for the manufacture of hard stoneware or some forms of terra-cotta, &c. The marly clays and shales from the Silurian limestone strata are remarkable for their large proportions of potash; the one from the Lower Silurian in Fayette county giving nearly eight per cent. of that alkali. They also have considerable quantities of lime, iron oxide, &c., and no doubt all contain phosphoric acid, so that their use as fertilizing top-dressing on exhausted light soils might be locally beneficial. They are too fusible for some kinds of pottery, yet might be made into drain-tiles and similar products, or, in some cases, into stone-ware.

The thirteen *limestones* reported in the following pages are mostly from Madison county; one only from Franklin county; and are interesting mainly because the composition of several of them indicates their probable availability for the manufacture of *hydraulic cement*. It is true that imperfect trials made

of some of these, in the laboratory, with insufficient appliances, did not give decidedly favorable results in this relation; yet, probably, by a more perfect mode of calcination, adapted to their nature, the hydraulic properties might be developed.

For the purpose of comparison, the writer has appended to the table of the composition of these limestones, at the end of this Report, that of two undoubtedly good hydraulic limestones, copied from previous volumes of Reports of Kentucky Geological Survey.

It seems, however, that although we may learn much from the ultimate chemical composition of limestones, as to their availability for hydraulic cements, there are some necessary conditions to the production of these useful compounds not yet fully understood or appreciated, as is proved by the circumstance that while two different limestones may show, by analyses, nearly similar chemical compositions, they may yet give products, when calcined, which differ greatly in their value as hydraulic cements.

These conditions may possibly be physical, or what is more probable, the silica in the two limestones may be under different chemical relationships. Probably the impure limestone, which gives the best cement by calcination, has its silica already more or less naturally combined with lime or other bases, as silicates or hydrated silicates; while in the other, of similar ultimate composition, the silica may be more in a separated, insoluble state, or in firmer combination with other elements. This supposition is rendered probable by the fact that there are natural hydrated silicates which possess, to an eminent degree, the property of forming good hydraulic cements by simple mixture with pure quicklime and water. The best known of these, the volcanic tufa found near Naples, called Pozzuolana, is found to contain a large proportion of soluble silica in the form of hydrated silicates; and it has been found by experience, that when the water of its silicates is driven off by calcination, it loses its valuable hydraulic properties. Most of these Pozzuolanas contain a considerable proportion of alkalies, varying from more than one to about ten per cent., and in the artificial compounds of this kind made by calcining certain marly clays, at a heat sufficient to burn lime, it is probable that the well-known large proportion of alkalies generally found in these clays is essential in bringing the silica into a soluble condition.

It is now pretty generally acknowledged by men of science that the property of hardening under water depends on the presence or formation of silicate of lime in the cement. In this connection it may be well to observe, that in the analysis of the hydraulic limestone from Indiana, No. 1068, referred to above, it was found that as much as three per cent. of silica, soluble in a boiling solution of carbonate of soda, was contained in this uncalcined limestone. This amount of silica undoubtedly existed in the rock, in the form of silicate easily decomposable by acids, having been separated by the acids in the soluble or gelatinous form. After the calcination of this limestone, the proportion of the soluble silica was increased to more than fourteen per cent. of the calcined rock. In some of the Ohio Falls hydraulic cement, which had been hardened under water about twenty-eight years before it was analyzed by the writer, he found more than six per cent. of the silica yet in a soluble condition. (See Vol. IV, O. S. Ky. Geol. Reports, p. 190.)

As the property of hardening under water seems to depend on the formation of a silicate of lime, probably also sometimes of silicates of magnesia or of iron, the essential conditions for hydraulic lime are not only the presence of a sufficient amount of silica to form the hard compound which resists the solvent action of water, but also that the silica should be in a form favorable to its combination with the lime or other bases, as well as, most probably, the presence of substances which, like the alkalies, may aid in bringing about this combination. The alkalies, potash, and soda seem to be the best agents in promoting this action, and it has been found by experience, in the manufacture of the celebrated artificial Portland cement, by calcining a mixture of chalk and clay, that the addition of a half to one per cent. of soda is greatly beneficial. Magnesia also seems to exert a favorable action; indeed, some mag-

nesian limestones, which contain but a small proportion of silica, make good hydraulic cement, if calcined at a moderate red heat only; and most of our hydraulic limestones are magnesian. Pure calcined magnesia, one of the most insoluble of the earths, will set quite hard with a proper quantity of water. It is probable, as already hinted, that the oxide of iron may be useful in hydraulic cements, by increasing their hardness and durability, as may also alumina.

In the manufacture of the artificial Portland cement, a mixture of impure carbonate of lime, chalk, and clay from various sources, is finely powdered and intimately blended, and then calcined at a heat sufficient to cause a commencement of vitrification; and the best proportions are found to be from twenty-one to twenty-three of clay to seventy-nine to seventy-seven of chalk. Clay from different localities varies in its proportion of silica as much as from less than fifty to nearly eighty per cent., causing variations in the properties and value of the cement.

A very good cement, of the kind employed at Boulogne, France, is reported to have the following *composition:*

Lime	65.00
Magnesia	trace.
Alumina and iron oxide	8.70
Alkalies	.45
Silica	24.45
Water	.80
	99.40

It is generally said, that if the proportion of lime falls below 39.8 per cent.—equal to 70 per cent. of carbonate of lime in the uncalcined mixture—the obtained cement may harden quickly, but will not be durable.

Another very good artificial cement of this kind, reported by scientific writers, is that made by M. St. Leger, near Paris, France, by calcining an intimate mixture of the chalk of Meudon with 14.3 per cent. of the clay of Vannes. The composition of this, after burning, is reported to be—lime, 75.60; silica, 15.86; alumina, 7.93, and iron peroxide, 1.62 per cent. It is said to be wholly soluble in acids.

These remarks and quotations may aid in estimating the probabilities of the utility of our impure limestones, &c.

BALLARD COUNTY.

SOILS AND SUBSOILS.

No. 2096—SOIL LABELED "*Top soil from the 'Barrens;' four years in cultivation in tobacco, three years in corn, and four in wheat; the last and present year (1878) in tobacco. Farm of W. H. Reeves, about six miles north of Blandville.*" *Collected by John R. Procter.*

The dried soil is in friable lumps, of a dirty yellowish-brown color. The coarse sieve* separated a few soft, ferruginous concretions and a small quartz pebble.

No. 2097—"*Subsoil of the field above described. Sample taken twelve to eighteen inches below the surface.*" *Collected by John R. Procter.*

The dried subsoil is in friable clods; its color is somewhat lighter than that of the preceding. The coarse sieve removed from it only a few small, rounded ferruginous concretions.

No. 2098—"*Subsoil of the uplands around Blandville. Taken from eighteen to twenty-four inches below the surface. Characteristic of most of the upland subsoil in the Jackson Purchase. A silicious loam above the Paducah gravel.*" *Collected by Jno. R. Procter.*

The dried subsoil is in pretty firm lumps, of a handsome brownish-buff or ochreous color, mottled with lighter and darker tints. All passed through the coarse sieve.

No. 2099—"*Subsoil or under-clay of the uplands around Blandville. Taken several feet below the surface. It crops out just below the gravel bed, and is several feet thick. It is observed nearly all over the 'Jackson Purchase' where there is much soil.*" *Collected by John R. Procter.*

The dried subsoil is of a brownish-buff color, mottled with somewhat lighter colored, and showing some thin, dark-colored infiltrations of iron and manganese oxides. All of it passed through the coarse sieve.

* The coarse sieve used has about 64 meshes to the centimetre square.

No. 2100—"*Virgin soil. Top soil of bottom land, near Shelton and Moore's Mill, on Mayfield creek. Said to produce good hay, but to be otherwise unproductive. Primitive growth, black, white, and red oak, sweet gum, elm, persimmon, and hickory.*" *Collected by John R. Procter.*

Dried soil of an umber-grey color, in quite friable clods, apparently containing much fine sand. The coarse sieve removed from it only a few small, partly-rounded quartz particles.

No. 2101—"*Top soil from an old field long in cultivation. Bottom land, on Mayfield creek.*" *Collected by John R. Procter.*

The dried soil is slightly lighter colored than the preceding, and more yellowish. The coarse sieve removed only a few small silicious particles.

No. 2102—"*Subsoil of the next preceding. Bottom land on Mayfield creek.*" *Collected by John R. Procter.*

Clods more firm than those of next preceding, and lighter colored, mottled with lighter colored and ochreous tints. The coarse sieve removed from it a small quantity of small silicious gravel.

COMPOSITION OF THESE BALLARD COUNTY SOILS, DRIED AT 212° F.

	No. 2096	No. 2097	No. 2098	No. 2099	No. 2100	No. 2101	No. 2102
Organic and volatile matters	4.065	2.790	2.185	1.565	3.210	2.565	2.125
Alumina & iron & manganese oxides	5.904	7.597	8.557	7.835	6.150	3.864	5.088
Lime carbonate	1.095	.295	.195	.645	.155	.385	.245
Magnesia	.394	.308	.544	.601	.268	.163	.184
Phosphoric acid (P_2O_5)	.246	.093	.093	.140	.115	.061	.077
Potash, extracted by acids	.289	.449	.131	.175	.203	.319	.276
Soda, extracted by acids	.242	.148	.653	.309	.364	.362	.129
Water, expelled at 380° F.	.935	.760	.450	.435	1.065	.635	.675
Sand and insoluble silicates	87.120	87.395	87.110	87.495	88.890	92.010	91.570
Total	100.292	99.835	99.918	99.200	100.420	100.364	100.369
Hygroscopic moisture	2.000	2.300	2.735	2.300	1.865	1.075	1.125
Potash in the insoluble silicates	1.619	1.482	1.085	2.138	1.659	1.358	1.401
Soda in the insoluble silicates	.680	.674	.536	1.208	1.150	.616	.911
Character of the soil	Surface soil	Subsoil.	Subsoil.	Subsoil or under-clay	Virgin soil	Old field soil.	Subsoil.

Some differences were observed in the silicious residue or sand and insoluble silicates of these several soils, when sifted with fine bolting-cloth, which had about 900 meshes to the centimetre square. For example, while that of Nos. 2096, 2097, 2098 all passed through except very few small hyaline or reddish quartz particles, Nos. 2099 and 2100 left upon the bolting-cloth a considerable proportion of small particles of partly decomposed silicates or concretions; the silicious skeletons, as it were, of these substances, from which most of their soluble ingredients had been removed by the acids in which they had been digested, were generally so soft as to be easily crushed under the finger; after which crushing, they readily passed through the bolting-cloth. The bolting-cloth also separated from them a few small quartzose particles, hyaline, opake, and reddish. No. 2101 left none of these sóft remains of decomposed concretions on the bolting-cloth, but a few small quartzose particles; while No. 2102 gave a few of these soft, partly-decomposed particles, and rather more of the small quartzose granules than the next preceding soil.

These Ballard county soils, if well drained, no doubt are good productive soils under good management. In all of them, however, except, perhaps, No. 2096, the proportion of organic and volatile matters is quite small, and this, as might be expected, is particularly to be noticed in the deep subsoil or under-clay, No. 2099; but this deficiency might be supplied by the culture of clover or other green crops, to be plowed under after or without grazing. They all contain enough of lime and magnesia, as well as of potash and soda; some of them, indeed, contain more than the average proportion of these essential alkalies, not only in a condition to be immediately available for plant nourishment, but also as a considerable reserve in the insoluble silicates. Nos. 2097, 2101, and 2102, containing but a moderate proportion of phosphoric acid, would no doubt be greatly increased in fertility by the use of phosphatic fertilizers, such as ground bone, superphosphate, guano, &c. Nos. 2101 and 2102 contain more than the average proportion of fine sand and insoluble sili-

cates, and but a small quantity of alumina, &c., &c., and consequently may be less durable naturally than some of the others; but the state of very fine division of their silicious constituents compensates, measurably, the paucity of the clay ingredients. The so-called "barrens" soil is one of the richest of them all.

CLAYS OF BALLARD COUNTY.

No. 2103—"*Ochreous Clay, from southern part of Ballard county.*" *Collected by John R. Procter.* "*Will it make a good and durable paint? Found in several parts of this county.*"

In friable lumps of a yellow ochre color, with some little infiltration of whitish material. It becomes soft and plastic when placed in water. Mixed up with a large quantity of water, and allowed to stand at rest for a few minutes, a portion of fine sand, equal to about twenty-six and a half per cent., settles to the bottom of the mixture, while the ochreous material remains suspended in the water for a considerable time in consequence of its fine state of division.

This fine sand is composed of small, rounded grains of transparent quartz, colored light buff by a little adhering ochreous material; it contained a few small spangles of mica.

It would be easy, by this simple process of washing, to separate the ochre from the fine sand with which it is naturally mixed. The washed ochre, although not very bright, is of a good color, and could be very well used for a cheap and durable paint for outside work. Calcined in the fire, it becomes of a good Venetian red color.

No. 2104—"*Clay, at least four feet thick, from near Moore's Mill. Base of hill on the north side of the Columbus and Blandville road; one mile southwest of Blandville.*" *Collected by John R. Procter.*

Clay in friable lumps; generally of a very light grey color, nearly white; mottled somewhat with ochreous material. It is quite plastic with water, and calcines of a light salmon color.

Quite refractory before the blow-pipe. Washed several times with water, allowing ten minutes each time for subsidence, it left nearly 48 *per cent. of quite fine white sand*, which was so fine, indeed, that it was somewhat plastic while wet, and adherent when dry.

On comparing the composition of this clay with that of the celebrated German Glass Pot Clay, so extensively imported by our glass manufacturers, a remarkable resemblance is observable. That the comparison may be made by our readers, we copy here the results of two analyses of the German clay, from Geological Reports of Kentucky, Vol. IV, N. S., p. 163, marked H and I, and place them by the side of that of the clay above described, No. 2104, as follows:

COMPOSITION, DRIED AT 212° F.

	No. 2104.	H.	I
Silica, including pure sand	74.460	70.860	73.660
Alumina	18.070	20.900	19.460
Iron peroxide	1.633	1.560	1.560
Lime	.314	.347	.168
Magnesia	.245	.220	.209
Potash	.940	.578	.520
Soda	.021	.112	.046
Water expelled at red heat and loss	4.317	6.800	6.200
Total	100.000	101.377	101.823

If this clay is in sufficient quantity in this locality, it certainly deserves trial in the glass-house for this important use, as the importation of the German clay for glass pots, now considered indispensable, is quite expensive. At all events, this No. 2104 is quite a refractory fire-clay, although it contains more potash than the imported article, which may possibly impair its value in this respect.

Other sandy clays; one from Graves county, No. 2143, and one from Hickman county, No. 2162 of present report, closely resemble this in composition, but containing rather more potash; also deserve trial in this relation.

No. 2105—"*Clay, from the farm of Mr. T. D. Campbell, in South Ballard county.*" *Sent by John R. Procter.*

In a friable lump, as soft as chalk, of a handsome, light purplish-grey color, presenting a somewhat stratified appearance, because of interrupted thin laminæ of lighter material. It shows a few ochreous specks, and appears to be somewhat sandy.

Washed in water, it left fifty-four per cent. of very fine sand of a light lilac color, some more of still finer sand being left in the washings. It is quite plastic, decrepitates strongly when exposed to heat, unless it is thoroughly dry. Calcines hard; of a handsome light purplish-grey color. Before the blow-pipe it proved quite refractory.

COMPOSITION, DRIED AT 212° F.

Silica	67.501
Alumina, &c.	23.051
Iron peroxide	2.109
Lime	.257
Magnesia	.065
Potash	.412
Soda	.020
Combined water, &c., and loss	6.585
Total	100.000

This clay would, no doubt, answer well for many forms of pottery, as well as for fire-bricks. But for the somewhat undue proportion of iron oxide, it might probably serve all purposes of the most refractory clay.

No. 2106—"*Impure sand, from T. D. Campbell, southern part of Ballard county.*"

A dirty, olive-brownish sand, abundantly mixed with ochreous or ferruginous material, mottled with blackish, containing some ochreous sandy concretions.

Digested in chloro-hydric acid, it left nearly ninety-eight per cent. of sand, composed mostly of rounded grains of hyaline quartz, mixed with some very fine sand, and some few rounded pebbles of milky quartz of various sizes. The acid dissolved out of it less than two per cent. of alumina and iron and manganese oxides, with traces of lime, magnesia, &c.

This sand would answer well for the manufacture of the common kinds of glass in extensive use, as well as for mixing with cement and mortar for building purposes, &c.

MINERAL WATERS FROM BALLARD COUNTY.

No. 2107 A—" *Water from the 'Bluff Spring.' On the road from Columbus to Cairo, in the milk-sick region, and supposea by some to cause this sickness." Sent for examination by Hon. S. H. Jenkins.*

The water had deposited a considerable brownish sediment, which did not all dissolve in chloro-hydric acid.

Qualitative analysis showed the presence of some free carbonic acid, much of bi-carbonates of lime and magnesia, some little bi-carbonate of iron, and of chlorine and sulphuric acid in combination.

The water had a slightly alkaline reaction, and the spectroscope showed the presence of a trace of lithium. There is no reason to suppose that this water has anything to do with the causation of milk-sickness.

No. 2107 B—" *Water from the 'Mahon Spring.' Said to be unhealthy, and by some thought to cause milk-sickness." Sent by Hon. S. H. Jenkins.*

Qualitatively examined, it gave similar reactions with the water from the "Bluff Spring," but did not seem to contain as much iron; and there was no brown sediment in the bottle containing it.

A weighed portion of this water, evaporated to dryness, left only 0.36 per thousand of the water of whitish saline residue, dried at 212°. The soluble part of this had an alkaline reaction, and the spectroscope showed the presence in it of soda and lithia.

It seems to be a perfectly wholesome water, although, like the above, somewhat "hard" from the presence of lime and magnesia bi-carbonates. The water A is also slightly chalybeate.

CLARK COUNTY.

No. 2108—" *Water from a bored well, seventy-two feet deep, near Winchester. Bored through limestone and so-called 'soapstone' (or marlite)." Brought by Mr. B. F. Vanmeter, and analyzed for him.*

The water was slightly alkaline in reaction, contained no hydrogen sulphide, and had formed no sediment in the bottle in which it was brought to the laboratory.

Evaporated to dryness, 1000 parts of the water left only 0.5912 part of saline matters, dried at 212° F. These were quite alkaline in reaction, and the spectroscope showed the presence in them of soda, lithia, potash, strontia, and a doubtful trace of baryta.

Qualitative analysis detected much chlorine, some carbonic acid, and a little sulphuric acid, in combination with a considerable proportion of lime and magnesia, as well as with the bases above mentioned, but no sensible quantity of iron.

This water is much more free from saline matters and hydrogen sulphide than what is usually obtained by boring to such a depth in this limestone region.

CLINTON COUNTY.

SOILS.

No. 2109—" *Virgin soil from the farm of Lewis Huff, at the north end of the 'Copperas Knob,' at Huff's coal bank; one mile east from the 'Livingston road' and from Mr. Huff's house; about three miles west of south of Long's Gap. Geological position, on the first terrace above the sub-carboniferous limestone, and the second below coal, and on the steep terrace slopes of the coal-bearing sandstone and shales." Collected by Joseph Lesley, jr., July,* 1859.

The dried soil is friable, and of a dark umber-grey color. The coarse sieve separated from it 22.4 per cent. of irregular, slightly-rounded fragments, some pretty large, of ferruginous sandstone or silico-ferruginous concretions. The analysis given below was of the "fine earth" separated from these fragments by the coarse sieve; and the ultimate value of these soils must therefore be discounted by the amount of these coarse, rocky fragments thus separated. The bolting-cloth removed from the silicious residue (stated as sand and insoluble silicates) a considerable proportion of small grains of partly decomposed concretions or silicates, easily crushed to fine powder, and a few small, rounded quartzose particles.

No. 2110—"*Surface soil from the same field as the preceding. Was cleared in* 1853. *Has been in corn every year, including the present* (1859)." *Collected by Jos. Lesley, jr.*

The dried soil resembles the preceding; is very slightly darker than that. The coarse sieve removed from it 27 per cent. of ferruginous silicious fragments; some large; not rounded.

The bolting-cloth separated from the sand and insoluble silicates only a small proportion of particles of partly-decomposed concretions or silicates, and a very few small, rounded grains of white quartz.

No. 2111—"*Subsoil of the next preceding,*" *&c., &c.*

This subsoil is slightly darker colored than the preceding, which it resembles. The coarse sieve removed from it 14.2 per cent. of irregular fragments of ferruginous sandstone, not much rounded, and a few small, rounded quartz pebbles.

All the silicious residue, from digestion in acids, passed through the bolting-cloth, except a small proportion of soft particles of partly-decomposed silicates or concretions, and very few small, rounded quartz grains.

No. 2112—"*Virgin soil from the farm of John Wade, on the head of Indian creek, on the Monticello and Albany road, sixteen and three quarter miles southwest of the former place, and seven miles northeast of the latter; one mile north of Wade's Gap, and at the south foot of 'Short Mountain.' Geological position, sub-carboniferous limestone.*" *Collected by Joseph Lesley, jr.*

This dried soil is of a light brownish-grey color. It is quite friable and light. The coarse sieve separated from it as much as 29.5 per cent. of angular fragments of chert and somewhat rounded particles of ferruginous sandstone. All of its silicious

residue passed through the bolting-cloth except a small proportion of small, rounded grains of white quartz, and a few particles of partly decomposed silicates or concretions.

No. 2113—"*Surface soil from a field across the road from the place of the next preceding. Now* (1859) *in corn; last year in wheat; year before in grass. Was cleared in* 1803, *and for twelve years was set uninterruptedly in corn, and has been cultivated ever since, with not enough manure to speak of.*" *Collected by Joseph Lesley, jr.*

The dried soil is of a light snuff color, but darker colored and more brownish than the next preceding; friable. The coarse sieve removed only 4.4 per cent. of somewhat rounded ferruginous sandstone fragments, with a few small quartzose concretions. All the silicious residue passed through the bolting-cloth, except a small proportion of small, rounded white quartz grains and a few of partly decomposed silicates or concretions.

No. 2114—"*Subsoil of the next preceding,*" *&c., &c.*

This dried subsoil is very much like the soil next preceding, but is of a slightly darker color. It is quite friable. The coarse sieve separated from it 8.2 per cent. of somewhat rounded particles of ferruginous sandstone. All the silicious residue passed through the bolting-cloth, except a small proportion of small rounded grains of white quartz and a few of partly decomposed silicates or concretions.

COMPOSITION OF THESE CLINTON COUNTY SOILS, DRIED AT 212°.F.

	No. 2109.	No. 2110	No. 2111	No. 2112.	No. 2113.	No. 2114.
Organic and volatile matters	6.615	9.275	6.910	3.000	4.320	4.695
Alumina and iron and manganese oxides	5.984	6.687	6.951	2.932	6.129	6.247
Lime carbonate	.405	.620	.480	.080	295	.195
Magnesia	.232	.232	.223	.106	.124	.108
Phosphoric acid (P_2O_5)	.166	.173	.259	.093	.071	.093
Potash extracted by acids	.212	.274	.222	.155	.170	.188
Soda extracted by acids	not est.	not est.	not est.	not est.	not est.	not est.
Water expelled at 380° F.	1.400	1.810	1.665	1.550	1.940	1.500
Sand and insoluble silicates	84.990	81.165	83.365	92.240	86.790	86.790
Total	100.004	100 236	100.075	100.156	99.839	99.816
Hygroscopic moisture	1.585	1.990	1.750	0.900	1.800	1.515
Potash in the insoluble silicates	.983	.098	.972	.327	.726	.621
Soda in the insoluble silicates	.217	.101	.158	.269	.263	.169
Percentage of gravel	22.400	27.000	14.200	29.500	4.400	8.200
Character of the soil	Virgin soil	Old field.	Subsoil.	Virgin soil	Old field.	Subsoil.

These Clinton county soils are from two different geological horizons; Nos. 2109, 2110, and 2111 being from the coal-measure sandstones and shales, while Nos. 2112, 2113, and 2114 are based on the sub-carboniferous limestone. Strange as it may appear, these coal-measure soils seem to be the richest in essential ingredients. Were it not for the considerable proportion of ferruginous sandstone fragments or gravel contained in these, they might be classed amongst our most productive soils, as their "fine earth," the analyses of which are given above, contains a full average proportion of potash, phosphoric acid, lime, magnesia, organic matters, &c.

The soils Nos. 2112, 2113, and 2114 are somewhat deficient in phosphoric acid, and it is remarkable that No. 1112, the virgin soil of the set, is much poorer than the soil of the old field, No. 2113, which has been in cultivation for fifty-six years, and that it is quite deficient in lime carbonate as compared with that. But this fact, as well as its much larger proportion of gravel, of a different kind from that of the other, and its lighter color, as compared with the soil of the old field and the subsoil, indicate that this and these other soils were derived from different geological sources.

CRITTENDEN COUNTY.

SOILS.

No. 2115—"*Virgin soil; half an inch below the surface. Soil two to four inches deep. Ridge land a mile and a half east of the Sulphur Springs, Crittenden county. Farm of S. C. B. McMican. Soil is derived from sandstone. Supports a growth of black, white, post, Spanish, and some black-jack oaks, poplar, hickory, elm, ash, black gum, dogwood, and some sassafras and papaw." Collected by C. J. Norwood.*

A light soil, of a grey-buff or drab color. It all passed through the coarse sieve except vegetable débris.

All the sand and insoluble silicates left after digestion in the acid passed through bolting-cloth, except a small proportion of soft grains of partly-decomposed concretions, and a very few minute, rounded white quartz grains.

No. 2116—"*Subsoil of the next preceding," &c., &c.*

The subsoil is of a brownish-yellow ochre color, in quite firm clods. It all passed through the coarse sieve except some vegetable débris. The bolting-cloth separated from the sand and insoluble silicates more than half its weight of small, rounded particles of partly-decomposed concretions, easily crushed under the finger, and a very few small, rounded grains of white quartz.

No. 2117—"*Surface soil on ridge land; from a field in cultivation for eight years; 1st in tobacco, 2d and 3d in corn, 4th in wheat, 5th, 6th, 7th, and 8th in corn. No fertilizers used. The soil is from three to six inches deep, derived from sandstone. Sample taken one inch from the surface. Same farm as the two preceding." Collected by C. J. Norwood.*

All passed through the coarse sieve except vegetable débris and a few small ferruginous concretions. The bolting-cloth separated from the silicious residue only a small proportion of particles of partly-decomposed concretions, and a very few minute, rounded grains of white quartz.

No. 2118—"*Subsoil of the next preceding," &c., &c.*

The dried subsoil is of a greyish-yellow ochre color; lighter than that of the virgin soil. It is in somewhat firm clods, but it all passed through the coarse sieve.

The bolting-cloth removed from the sand and insoluble silicates about half their weight of small soft particles of partly-decomposed concretions or silicates, and only some three or four small, rounded grains of white or hyaline quartz.

COMPOSITION OF THESE CRITTENDEN COUNTY SOILS, DRIED AT 212° F.

	No. 2115.	No. 2116.	No. 2117.	No. 2118.
Organic and volatile matters	2.225	2.950	3.260	2.885
Alumina and iron and manganese oxides	3.629	8.718	4.868	8.173
Lime carbonate	.160	.145	.270	.170
Magnesia	.304	.350	.214	.703
Phosphoric acid (P_2O_5)	.086	.092	.067	.102
Potash extracted by acids	.090	.309	.171	.122
Soda extracted by acids	n. e.	.118	n. e.	n. e.
Water expelled at 380° F.	.875	.925	1.225	.950
Sand and insoluble silicates	92.705	86.665	89.440	86.490
Total	100.074	100.272	99.515	99.595
Hygroscopic moisture	0.890	0.925	1.565	2.000
Potash in the insoluble silicates	1.876	2.023	1.707	1.755
Soda in the insoluble silicates	.896	.750	.694	.588
Character of the soil	Virgin soil	Subsoil.	Old field.	Subsoil.

These soils, although derived from sandstone, and containing a considerable proportion of sand and insoluble silicates; in No. 2115 as much as 92.705 per cent.; may yet be preserved in a fertile condition for an unlimited time by judicious management and the use of appropriate fertilizers. What we denominate "sand," however, in the statement of the composition of these and other soils, is in such a state of fine division as to pass freely through a sieve having 1600 meshes to the centimetre square; and while it renders the soil light and readily permeable by water and the gases, is yet so finely divided as to present in some degree the plastic properties of clay, as well as the property of attracting and holding, with surface attraction, the gases and the fertilizing materials with which it is brought in contact.

The influence of fine division of the soil has been recognized by experience, so that the German and French agricultural chemists mainly disregard the pebbles and coarse sand which enter into the composition of a soil, and estimate its fertility by the proportion and composition of the "fine earth" which it contains. This, indeed, has been the method pursued in this work for the Kentucky Geological Survey.

The soils above described contain quite a sufficient quantity of lime and magnesia, and, generally, a good proportion of potash; the ridge soil, No. 2115, showing, however, a slight deficiency in this respect; but as the phosphoric acid appears to be in rather small amount in them, the use of phosphatic fertilizers would doubtless be profitable; associated, as they always should be, with some nitrogenous material. Their fertility might, no doubt, also be improved by increasing their proportion of organic matters, by the use of barn-yard manure, or plowing under green crops, &c. Deep plowing might also be advantageous, as the subsoil is rather richer than the surface.

FAYETTE COUNTY.

No. 2119—"*Salt sulphur water from a bored well seventy-one feet two inches deep; six feet and a half of which was through soil, subsoil, and under-clay; the rest through the hard limestone rock of the Lower Silurian formation. On the farm of Mr. John C. Innis, on the Russell road, about seven miles north of Lexington.*" *Brought by Mr. Innis.*

The water contained hydrogen sulphide in notable quantity, and carbonic acid. Evaporated to dryness, it left 2.2 parts of *saline matters*, dried at 212°, to the thousand of the water, which gave a slightly alkaline reaction with reddened litmus.

By qualitative analysis the saline matters of this water were found to contain much sodium chloride (common salt); also much lime in combination, some magnesia, and a small quantity of sulphates, &c.; in short, the usual saline constituents of the rocks of this region, which lie below the surface drainage; found in the waters of almost all the deep-bored wells, and brought out in the waters of such deep-seated springs as those of the lower Blue Licks, &c., and which are derived originally, no doubt, from the primeval ocean under which the rock strata were formed.

No. 2120—"*Marly clay, occurring in a bed described as being a foot and a half thick, in the Lower Silurian limestone strata on Elk Lick, between the Kentucky river and the Lexington and Richmond Turnpike, just above the so-called 'petrified falls' of Elk Lick.*" *Collected by Waldemar Mentelle.*

A whitish clay, mottled with brownish ochreous. Quite plastic. Effervesces with chlorohydric acid. At a moderate red heat it calcines (or "burns") of a handsome flesh color, which property might commend it for use for terra-cotta, if in sufficient abundance. Before the blow-pipe it readily fuses into a whitish slag.

COMPOSITION, DRIED AT 212° F.

Silica	53.780
Alumina	23.260
Iron peroxide	1.300
Lime	4.866
Magnesia	.568
Phosphoric acid (P_2O_5)	.191
Potash	7.612
Soda	.550
Combined water, carbonic acid, and loss	7.873
Total	100.000

The considerable proportions of lime, magnesia, potash, and soda account for the fusibility of this clay at a high temperature. It resembles the usual marly clay layers of the Lower Silurian formation, and contains quite a large proportion of combined potash.

FRANKLIN COUNTY.

No. 2121—"*Limestone, supposed to be hydraulic or water lime. Kentucky river bluffs; north side; at the end of Dam No. 4. Bed three to ten feet thick. Trenton Group.*" *Collected by John R. Procter.*

A pretty compact or fine granular rock; not adhering to the tongue. Some layers laminated and slightly adherent. Generally of a dull, dark brownish, olive-grey color. Contains a few indistinct, small encrinital joints in the compact portion.

COMPOSITION, DRIED AT 212° F.

Lime carbonate	70.360	= Lime, 39.401
Magnesia carbonate	6.784	= Magnesia, 3.236
Alumina	5.458	
Iron peroxide	1.342	
Phosphoric acid	not est.	
Potash	1.118	
Soda	.281	
Silica	14.020	
Total	99.363	

Some of the rock was calcined at a moderate red heat in the powdered state, for about one hour. It still effervesced a little with acids. Mixed with water into a paste, both with sand added and without, and partly immersed in water, both samples became only moderately hard. A portion was then calcined at a white heat, so that it became partly sintered, but the powdered product did not harden as well even as that which had been more moderately heated. It seems, therefore, that this does not promise well as a water cement when calcined without admixture. Comparing it with the celebrated water cement rock prepared near the Falls of the Ohio, near Louisville (see table at end of this report), we find that, while this Kentucky river rock contains a larger proportion of potash than that, it is relatively deficient in silica as compared with its lime. Indeed, we found that when calcined it slacked hot with water, and showed other properties of "fat" lime.

No. 2122—"*Water from the Kentucky river, collected just below the bridge at Frankfort,*" *by John R. Procter. Brought to the Laboratory in a new, well-glazed stone-ware jug, stopped with a cork.*

The water was slightly turbid, and deposited a light brownish-red sediment on standing, which contained very fine sand and red oxide of iron. It is slightly alkaline in its reaction, and left, on evaporation to dryness, only about 0.13 to the thousand parts of the water of solid saline residue, dried at 212 F. This saline residue was very slightly colored with brownish organic matter, and consisted mainly of carbonates of lime and magnesia, which were held in solution in the water by carbonic acid; some chlorides, no doubt, of potassium, sodium, &c.; a small amount of sulphate of some of the bases mentioned; a trace of alumina and iron and manganese oxides, and a little dissolved silica.

Were it not for the trace of reddish organic matter in this water, it would be, after its sediment had been deposited by allowing it to stand at rest or removed by filtration, a remarkably good natural water; and it is probable that it would be found more free from saline and other impurities if collected above the limits of the town. It would be interesting and useful more fully to examine the water of this river, as well as of our other rivers, at different seasons of the year, especially because the use of these waters may greatly affect the health of the public; and the successful practice of many of the industrial arts depends on pure water.

FULTON COUNTY.

SOILS.

No. 2123—"*Top soil, from Mississippi bottom land, three miles southwest from Hickman, Fulton county. Principal growth. white oak, hickory, gum, and beech.*" *Collected by John R. Procter.*

The dried soil is in pretty firm clods, of a light yellowish-umber color. The coarse sieve * removed from it only a very small portion of vegetable débris. All of its silicious residue, left after digestion in acids, passed through the fine† sieve, except a small proportion of small particles of partly decomposed concretions, and only one or two small quartz grains.

No. 2124—"*Soil from the surface of a field twelve years in corn without manure. Mississippi bottom land, about two miles south of Hickman. Yield this season* (1878) *over fifty bushels of corn per acre.*" *Collected by John R. Procter.*

Dried soil in friable clods, of an umber color.

* The coarse sieve has about sixty-four meshes to the centimeter square.

† The fine sieve has about 1600 meshes to the centimeter square.

No. 2125—"*Virgin soil, from the land of Dr. G. W. Pascal, half a mile north of Fulton, Fulton county.*" *Collected by John R. Procter.*

The dried soil is in quite friable clods, of a light grey-brown color.

No. 2126—"*Surface soil, from an old field forty years in cultivation. Farm of Dr. Pascal, half a mile from Fulton. Sample taken three to twelve inches below the surface.*" *Collected by John R. Procter.*

The dried soil of a light yellowish grey-brown color. Clods friable.

No. 2127—"*Subsoil of the next preceding. Taken from thirteen to twenty inches below the surface.*" *Collected by John R. Procter.*

The dried subsoil is of a brownish-buff color. The clods are more firm than those of the preceding soil. The silicious residue of this, as well as of the other soils of this locality, described above, all passed through the bolting-cloth, except a very small proportion of small grains of partly-decomposed concretions, and of quartz. The soils all passed through the coarse sieve, with a small residue in some of vegetable débris and small ferruginous concretions.

No. 2128—"*Virgin soil. Farm of Capt. Henry Tyler, three miles southeast from Hickman, Fulton county. Growth: mostly poplar, maple, white and Spanish oaks, and some walnut.*" *Collected by John R. Procter.*

The dried soil is of a brownish-grey color. The clods are friable, and mottled with lighter grey and light ferruginous tints. The coarse sieve separated from it but a small proportion of partly rounded ferruginous particles. Its silicious residue all passed through the fine sieve except a very small proportion of small, rounded particles of partly-decomposed concretions, with no quartz particles.

No. 2129—"*Subsoil of the next preceding, &c., &c.; taken twenty-four inches below the surface.*" *Collected by John R. Procter.*

The dried subsoil is of a grey-buff color. The clods are quite firm, mottled with darker and yellowish tints. The bolting-cloth removed from the silicious residue a considerable proportion of small, soft grains of partly-decomposed concretions, but no quartz sand.

No. 2130—"*Top soil, first ten inches from surface; from an old field near the location of the next preceding soil, on Capt. Henry Tyler's farm, &c., &c. The land is in corn, as it was last year. The yield this year* (1877) *is sixty-five bushels per acre. There is a good deal of soil similar to this on the uplands bordering on the Mississippi river. Noticed similar soil in the western part of Ballard county.*" *Collected by John R. Procter.*

The dried soil is of a dark mouse color. The clods are friable. The coarse sieve removed from it only a little vegetable débris.

The fine sieve separated from the silicious residue, left after digestion in acids, a notable proportion of small, soft, rounded grains of partly-decomposed concretions, and one or two quartz grains.

No. 2131—"*Subsoil of the next preceding; taken carefully from fifteen to twenty-four inches below the surface. The bulk of the sample is from twenty-four inches below the surface.*" *Collected by John R. Procter.*

The dried subsoil is in very firm clods, of a dark mouse color. The bolting-cloth separated from the silicious residue a very large proportion, about one half, of small particles of somewhat rounded, partly-decomposed concretions.

No. 2132—"*Virgin soil; upland. On Capt. Henry Tyler's farm. Timber, proportion in the order named: black walnut, white oak, sugar maple, and red oak.*" *Collected by John R. Procter.*

Dried soil in friable clods, of a dirty drab color. The coarse sieve separated only a small portion of vegetable débris. All the silicious residue, from digestion in acids, passed through the bolting-cloth, except a single small quartz grain.

No. 2133—"*Subsoil of the next preceding soil, from Capt. Tyler's farm; taken twelve to twenty-four inches below the surface.*" *Collected by John R. Procter.*

Dried subsoil in firm clods, of a dark buff color. All passed through the coarse sieve. The silicious residue all passed through the bolting-cloth, except a small proportion of soft granules of partly-decomposed concretions. It contained no quartz grains.

COMPOSITION OF THESE FULTON COUNTY SOILS, DRIED AT 212° F.

	No. 2123	No. 2124	No. 2125	No. 2126	No. 2127	No. 2128	No. 2129	No. 2130	No. 2131	No. 2132	No. 2133
Organic and volatile matters	9.305	4.725	3.075	2.300	2.535	3.090	2.285	8.375	4.140	2.860	2.165
Alumina and iron and manganese oxides	10.437	5.127	5.335	4.974	8.690	3.825	7.700	6.860	10.560	3.560	6.550
Lime carbonate	1.385	1.045	.360	.190	.195	.395	.145	1.395	.795	.345	.110
Magnesia	.461	.234	.175	.162	.331	.214	.268	.598	.169	.142	.232
Phosphoric acid	.198	.198	.055	.156	.125	.125	.115	.125	.115	.125	.140
Potash extracted by acids	.142	.321	.179	.290	.141	.066	.186	.332	.208	.074	.275
Soda extracted by acids	not est	.419	not est.	.124	.098	not est.	.142	.073	.317	.182	.050
Water expelled at 380° F.	3.110	1.150	1.025	.775	.900	1.050	.840	2.650	1.501	.975	.650
Sand and insoluble silicates	74.840	87.145	89.945	91.745	86.895	91.125	87.795	79.340	82.395	91.740	89.670
Total	99.878	100.364	100.149	100.716	99.910	99.890	99.476	99.748	100.200	100.003	99.842
Hygroscopic moisture	4.100	2.350	1.685	1.400	2.585	1.335	2.610	3.585	3.975	1.000	1.725
Potash in the insoluble silicates	1.889	1.814	1.767	1.664	1.892	1.784	1.675	1.865	1.873	1.969	1.935
Soda in the insoluble silicates	.607	.858	.828	.749	.715	1.208	.893	1.030	.841	.892	.991
Character of the soil	Top soil.	Cultivated soil.	Virgin soil.	Old field	Subsoil.	Virgin soil.	Subsoil.	Old field	Subsoil.	Virgin soil.	Subsoil.

There is a considerable resemblance between the soils Nos. 2123 and 2130. They both seem to be soils of more than average fertility, containing, as they do, large proportions of organic and volatile matters, and, consequently, of hygroscopic moisture; also more than the usual quantities of alumina, &c., of lime, magnesia, phosphoric acid, and the alkalies, and leaving but a moderate quantity of silicious residue when digested in acids. If well drained, these soils will doubtless be of durable fertility.

The soils Nos. 2126, 2128, and 2131 contain more of the silicious material than the above-mentioned, and Nos. 2128 and 2132 seem to be somewhat deficient in immediately available potash; but they contain an average proportion of lime, magnesia, phosphoric acid, and generally a large amount of reserve alkalies in their silicious residues. Moreover, being of a fine texture, their small proportions of alumina, &c., will not be as great a drawback to their productiveness as might be supposed. The other soils take an intermediate position between these two groups mentioned. No. 2125 is to be distinguished by its apparent deficiency of phosphoric acid, which, however, can be easily remedied by the judicious use of phosphatic fertilizers. Organic and volatile matters seem to be in small proportion in Nos. 2126 and 2132. The subsoil, No. 2127, also shows but a small proportion; but this is a common character of subsoils.

Although these soils vary considerably in their natural fertility and probable durability, there is no reason why they all may not be kept permanently productive with judicious management and the timely use of manures.

SILICIOUS RESIDUE OF SOILS.

Desirous of ascertaining whether any notable quantity of phosphoric acid, &c., had resisted the action of the acids used in the ordinary analyses of soils, in addition to the potash and soda, the presence and proportions of which have been determined in so many of these silicious residues, some of them, after thorough digestion in nitric acid, with the addition of a little hydrochloric acid in the process for the determination and removal of the soluble phosphoric acid, were analyzed by preliminary fusion with the alkaline carbonates and the approved processes, with the following results, viz:

COMPOSITION CALCULATED INTO 100 PARTS OF THE SILICIOUS RESIDUES, DRIED AT 212° F.

	No. 2123.	No. 2128.	No. 2132.	Average composition of 8 of these residues.
Silica	83.931	88.298	90.236	88.460
Alumina, with trace of iron	12.043	6.075	6.689	6.789
Lime	.791	.744	.600	not estimated.
Magnesia	.080	.043	.044	.569
Phosphoric acid	.077	.186	.039	1.151
Potash	2.524	1.947	2.147	} 3.295
Soda	.808	1.569	1.167	}
Total	100.254	98.862	100.922	100.264

It is interesting to note, in these silicates of the soil which have resisted the decomposing action of nitric and hydrochloric acids for a space of seven to ten days in the sand bath, so much of some of the essential elements of plants and animals usually to be found only in small proportion in soils. These, although in this present insoluble state, are, as in all other silicates, subject to gradual decomposition under the ordinary natural agencies, by weathering, as it is termed; and hence may be considered as a reserve store of plant-food, which may prolong the duration of the productiveness of soils. (See, under Nelson county, another of these analyses.)

CLAYS OF FULTON COUNTY.

No. 2134—"*Indurated clay from the bluff at Hickman; forty-five feet above low water.*" *Collected by John R. Procter.*

Clay generally of a grey color, with some light ferruginous stains in the fissures. Lumps quite firm when dry, breaking with an irregular fracture. Quite plastic with water when powdered. It calcines of a light buff color, and fuses before the blow-pipe into a grey slag.

No. 2135—"*Clay from the bluffs at Hickman; ninety-five feet above low water. Is it a fire-clay?*" *Collected by John R. Procter.*

In pretty firm lumps, generally of a light grey tint, but is considerably mottled with light brownish ochreous material.

Quite plastic with water. Calcines of a reddish buff color. It is refractory before the blow-pipe; but sintered somewhat.

No. 2136—"*Clay from Hickman bluff; upper part of the town. First clay beneath the gravel bed; about four feet thick. Tertiary formation.*" *Collected by John R. Procter.*

The dried clay is a light grey tint, colored buff and ferruginous in parts by infiltration. It is moderately plastic, and did not calcine very hard, acquiring a handsome light brick color. Refractory before the blow-pipe.

No. 2137—"*Clay from Hickman bluff, same bed as that of the next preceding, but a quarter of a mile further up the bluff; three to four feet thick.*" *Collected by John R. Procter.*

This clay is somewhat lighter colored than the preceding, and shows very little ferruginous infiltration. It is quite plastic. Burns hard, and of a light greyish-buff tint. Before the blow-pipe it fuses with great difficulty.

No. 2138—"*Clay from Hickman bluff, upper part of the town, about ten feet below the base of the gravel. Bed about four feet thick, with about four feet of potter's clay resting on it. It is probably the same as the clay collected from Hamby Hill. Tertiary.*" *Collected by John R. Procter.*

The dried clay is in pretty hard lumps, of a light grey color, infiltrated somewhat with ochreous material in striæ. Quite plastic. Calcined of a light brick color. Quite refractory before the blow-pipe.

No. 2139—"*Clay above the next preceding; about four feet thick.*" *Collected by John R. Procter.*

The dried clay is in moderately hard lumps, generally of a light lilac-grey, colored on the exterior ochreous and ferruginous. It is quite plastic; burns hard, of a light grey-buff tint. Before the blow-pipe it fuses with difficulty.

No. 2140—"*Clay from Hickman bluffs, upper part of the town; bed about five feet thick, below the next preceding. Tertiary.*" *Collected by John R. Procter.*

Dried clay, of a light lilac-grey color; in moderately hard lumps; stained with ochreous on the exterior. It is quite plastic. Burns quite hard, and of light brownish-buff tint. Quite refractory before the blow-pipe.

No. 2141—"*Clay; bed about twenty feet thick, or more; above the railroad track. Upper part of the town of Hickman. Tertiary.*" *Collected by John R. Procter.*

Dried clay, in moderately hard lumps; of a pretty uniform light olive-grey color. It calcines quite hard, and of a brownish-buff color. Quite refractory before the blow-pipe.

No. 2142—"'*Loess or Bluff' from Hickman bluff. Quaternary.*" *Collected by John R. Procter.*

In very friable lumps, of a light grey-buff color. Contains remains of land and fresh water shells. It is somewhat plastic; not very coherent when burnt; acquiring a very light brick color; before the blow-pipe fuses into a light grey slag.

COMPOSITION OF THESE HICKMAN BLUFF CLAYS, FULTON COUNTY, DRIED AT 212° F.

	No. 2134	No. 2135	No. 2136	No. 2137	No. 2138	No. 2139	No. 2140	No. 2141	No. 2142
Silica	64.800	76.860	83 380	71.340	83.500	71.080	74.100	77.960	68.860
Alumina	21.070	14.600	9.800	17.190	9 940	19.050	16.460	13.970	12.980
Iron oxide	5.270	3.020	2.120	2.770	2.500	2.810	2.700	2.390	2.240
Lime	1.400	.425	.963	1.612	.358	.627	.358	.134	9.587
Magnesia	.050	.308	.187	.209	.173	.401	.187	.163	1.182
Potash	.646	.736	.617	.925	.539	.578	.559	.797	1.773
Soda	.202	257	.118	.232	.109	.225	.135	.124	1.278
Combined water and loss	6.562	3.794	2.815	5.722	2.881	5 227	5.501	4.462	2.100
Total	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000

It is evident that the Tertiary bluffs, from which these clays were collected, offer some valuable materials to the industrial arts. Some of these are quite refractory in the fire, especially Nos. 2136, 2138, 2140, and 2141, and would probably make good fire-bricks, &c.; others of them could be employed for terra-cotta work and other forms of pottery; while some of these abundant deposits might, no doubt, be used with advantage, in mixture with the more calcareous soft material found in some of these beds, in the manufacture of hydraulic cement of the character of the celebrated Portland cement. The loess layer material might be made useful as top-dressing to heavy clay soil.

GRAVES COUNTY.

No. 2143—"*Clay, from Wm. P. Arnett's land, on Panther creek. The bed shows eight feet above the creek.*" *Collected by John R. Procter.*

Clay of a uniform grey color, apparently quite sandy. Washed with water, it left about sixty-three per cent. of fine sand of an umber-grey color, containing small spangles of mica and some coarser grains of transparent quartz. It is quite plastic, and burns of a light salmon color; does not become very hard unless exposed to a very high temperature. It is refractory before the blow-pipe.

COMPOSITION, DRIED AT 212° F.

Silica	75.550	Of which 63 per cent. of fine sand.
Alumina	16.751	
Iron peroxide	1.198	
Lime	a trace.	
Magnesia	.144	
Potash	1.094	
Soda	.216	
Combined water and loss	5.047	
Total	100.000	

This clay resembles that from Ballard county, No. 2104, which is compared with the German glass-pot clay; but both this and that contain more potash than the foreign material, which may possibly cause it to be less available to the glass-maker. It could no doubt be made useful for many purposes, as a fire-clay as well as for various pottery applications.

No. 2144—BITUMINOUS SHALE, *labeled* "*Brown coal, from Mr. Wm. Arnett's land, on Panther creek, six miles east of Mayfield, on the Columbus and Hopkinsville road. Bed showing about three feet above the creek, said to be several feet below that level.*" *Collected by John R. Procter.*

A soft laminated, bituminous shale or clay; of a dark chocolate color, showing numerous impressions of vegetable leaves.

COMPOSITION, DRIED AT 212° F.

Hygroscopic moisture	4.13	Total volatile matters = 20.35
Volatile combustible matters	16.22	
Fixed carbon in the coke	10.25	Total pulverulent coke = 79.65
Light ash, nearly white	69.40	
	100.00	100.00

The ash was found to contain a considerable proportion of alumina, some little lime and magnesia, as well as a trace of phosphoric acid. As this material only contains a little more than thirty-six per cent. of combustible matters, it could scarcely be made available as a fuel. Possibly it may find use as a cheap pigment.

GREENUP COUNTY.

COALS.

No. 2145—"*Coal (No. 3). Splint coal sampled from the stock pile of the Fulton Coal Company.*" *By John R. Procter.*

The coal breaks into irregular laminæ, which have some fibrous coal between them, and some fine, granular pyrites in parts. The fibrous coal shows the shape of portions of reed-like leaves in some of the laminæ. Generally the coal presents a glossy, pitch-like appearance.

No. 2146—"*Coal (No. 4). Cannel coal from Indian Run, Greenup county. Sampled from the stock pile of the Fulton Coal Company.*" *By John R. Procter.*

A very tough cannel coal; imperfectly and irregularly laminated, with no fibrous coal between the laminæ, and very little appearance of granular pyrites. It is generally of a dull black color, but some portions have an ebony-like gloss.

No. 2147—"*Coal (No. 4). Cannel coal from Chinn's Branch, three miles above Greenup. Sampled from the stock pile of the Fulton Coal Company.*" *By John R. Procter.*

This resembles the next preceding, but is not quite so much laminated; some portions give a large conchoidal fracture. It shows very little fibrous coal or granular pyrites.

No. 2148—"*Coal No. 7 (Coalton); from the Fulton Company tract. Sent for analysis by James A. Johnson. Average sample of a barge load.*"

A pure-looking, bright, pitch like coal, quite firm, with much handsome iridescence on some of the surfaces of its cuboid

blocks. It does not break into regular laminæ, although it shows irregular lamination, with very little fibrous coal between, and no visible granular pyrites. Has some bright pyritous scales in some of the joints.

COMPOSITION OF THESE GREENUP COUNTY COALS, DRIED AT 212° F.

	No. 2145	No. 2146	No. 2147	No. 2148
Specific gravity	1.319	1.286	1.331	1.324
Hygroscopic moisture	5.00	2.00	4.80	6.00
Volatile combustible matters	39.00	47.36	36.90	33.48
Coke	56.00	50.64	58.30	60.52
Total	100.00	100.00	100.00	100.00
Total volatile matters	44.00	49.36	41.70	39.48
Fixed carbon in the coke	49.88	38.24	51.20	56.14
Ash	6.12	12.40	7.10	4.38
Total	100.00	100.00	100.00	100.00
Character of the coke	Spongy.	Slightly coherent.	Dense.	Dense.
Color of the ash	Lilac-grey	Grey-buff.	Lilac-grey	Lilac-grey.
Percentage of sulphur	1.986	1.554	3.977	2.330

All of these are valuable coals, more especially Nos. 2145 and 2148, because of their small proportions of ash and sulphur. No. 2147 is nearly as good, but the sample analyzed contained more than the average proportion of sulphur. It is probable, however, that this excess of sulphur was accidental in the sample. The cannel coal, No. 2146, which would burn with much flame, would answer well under the steam-boiler or in the fire-place or cooking-stove.

HARRISON COUNTY.

No. 2149—"*Iron ore; from Thomas Hinkston's land.*" *Collected by John R. Procter.*

Generally in conglomeratic lumps, composed of dark colored, somewhat friable, limonite concretions, with some soft reddish ochreous material interspersed.

COMPOSITION, DRIED AT 212° F.

Iron oxide	21.200	= 14.84 per cent. of *iron.*
Alumina and phosphoric acid	12.870	
Lime carbonate	1.290	
Magnesia carbonate	6.621	
Silicious residue	49.690	
Water, &c., and loss	8.329	
Total	100.000	

It contains too little iron for use as an iron ore.

HENDERSON COUNTY.

SOILS.

No. 2150—"*Virgin soil; woodland pasture; bottom land. Farm of W. Thompson, five miles from Henderson Station, on the L. & S. E. Railroad. Said to be very fertile.*" *Collected by C. W. Beckham.*

The general color of this dried soil is dark drab. It contains some moderately firm clods, which, when broken, show a mottling of light ferruginous and bluish-grey tints.

It all passed through the coarse sieve, except some vegetable débris and a few small ferruginous concretions.

The bolting-cloth separated from the silicious residue, left after digestion in acids, a considerable proportion of small grains, the skeletons of decomposed concretions, with a small quantity of small, rounded white quartz grains.

No. 2151—"*Surface soil from a field fifteen years in cultivation in corn, tobacco, and hay. Same locality as the preceding.*" *Collected by C. W. Beckham.*

The dried soil is of a lighter drab color than the preceding, and the clods are not quite so firm. It all passed through the coarse sieve except vegetable débris and a few ferruginous concretions. Its silicious residue, from digestion in acids, all passed through the bolting-cloth, except a small quantity of small, soft particles of partly-decomposed concretions and a very few small, rounded quartz grains.

No. 2152—"*Subsoil of the next preceding,*" *&c., &c.*

The dried subsoil is in very firm clods, which are of a dark, brownish-drab color on the exterior surface, and mottled with brownish-ochreous and bluish-grey in the interior.

It all passed through the coarse sieve. The bolting-cloth separated from its silicious residue a very large proportion —more than one half of the whole—of small particles, the silicious skeletons of partly-decomposed concretions, which were easily crushed by the finger on paper, after which they passed through the bolting-cloth, leaving only a few small, rounded grains of quartz.

No. 2153—"*Surface soil from an old field twenty-five or thirty years in cultivation; said to be worn out. From the farm of J. D. Robsard, twelve miles from Henderson, on the St. L. & S. E. Railroad.*" *Collected by C. W. Beckham.*

The dried soil is in pretty firm clods, of a dirty brownish-buff color. It all passed through the coarse sieve. The bolting-cloth separated a considerable proportion of small, soft, rounded particles of partly-decomposed concretions from its silicious residue, as well as one or two small, rounded grains of quartz.

No. 2154—"*Subsoil of the next preceding,*" *&c., &c.*

The dried subsoil is in firmer clods than the preceding soil. It is of rather a handsome, warm, brownish-ochre color.

It all passed through the coarse sieve. The bolting-cloth separated from its silicious residue a larger proportion of small, soft grains of partly-decomposed concretions than from that of the preceding soil; but no quartz grains.

No. 2155—"*Virgin soil from woods pasture adjoining the field from which the next preceding two soils were taken. Farm of Mr. Kluté, near Henderson. Quaternary formation.*" *Collected by C. W. Beckham.*

This dried soil is quite friable and light, of a brownish ash-grey color. It all passed through the coarse sieve, except vegetable débris and a small quantity of shot iron ore. The bolting-cloth separated from its silicious residue only a very small proportion of particles of partly-decomposed concretions, and only two or three very small, rounded quartz grains.

No. 2156—"*Surface soil; in cultivation about thirty years; principally in corn, oats, clover, and tobacco. Same locality as the next preceding.*" *Collected by C. W. Beckham.*

The dried soil, also light and friable, is of a somewhat darker color than the preceding. It all passed through the coarse sieve, except a small quantity of shot iron ore and of vegetable débris. The bolting-cloth separated from its silicious residue only a small proportion of particles of partly-decomposed concretions, and a very few small, rounded quartz grains.

No. 2157—"*Subsoil of the next preceding, &c., &c. Used for making bricks.*" *Collected by C. W. Beckham.*

The dried subsoil is of a handsome brownish-yellow ochre color. The clods are very firm. The bolting-cloth separated from its silicious residue a large proportion of small, soft particles of partly-decomposed concretions, and no quartz grains.

No. 2158—"*Virgin soil from woods pasture. Farm of S. H. Busbey, ten miles from Henderson, on the St. L. & S. E. Railroad. Quaternary formation.*" *Collected by C. W. Beckham.*

Dried soil of a brownish ash-grey color. Light and friable. It all passed through the coarse sieve, except a small quantity of shot iron ore and vegetable débris. The silicious residue from digestion in acids all passed through the bolting-cloth, except two or three small particles of partly-decomposed concretions and two or three small quartz grains.

No. 2159—"*Surface soil from a field twenty-five years in cultivation, adjoining the location of the next preceding. Tobacco the only crop.*" *Collected by C. W. Beckham.*

The dried soil is light and friable; its color is slightly more yellowish or light-brownish than that of the preceding. It all passed through the coarse sieve, except vegetable débris and

a very small quantity of shot iron ore. Its silicious residue all passed through the bolting-cloth, except a very small proportion of small grains of partly-decomposed concretions and two or three small quartz grains.

No. 2160—"*Subsoil of the next preceding,*" *&c., &c.*

The dried subsoil is of a handsome brownish-yellow ochre color. The clods are quite firm. It all passed through the coarse sieve. The bolting-cloth separated from its silicious residue, left from digestion of the soil in acids, a large proportion of small, soft particles of partly-decomposed concretions, and only two or three very small quartz grains.

COMPOSITION OF THESE HENDERSON COUNTY SOILS, DRIED AT 212° F.

	No. 2150	No. 2151	No. 2152	No. 2153	No. 2154	No. 2155	No. 2156	No. 2157	No. 2158	No. 2159	No. 2160
Organic and volatile matters	4.525	3.150	2.780	2.125	2.900	3.465	3.025	3.290	3.835	2.785	3.350
Alumina and iron and manganese oxides	5.004	3.968	5.879	5.979	10.047	3.113	4.048	9.589	3.364	4.129	9.644
Lime carbonate	.570	.385	.520	.195	.130	.120	.195	.950	.220	.220	.195
Magnesia	.317	.241	.304	.245	.304	.166	.196	.342	.175	.309	.195
Phosphoric acid	.131	.102	.061	.061	.093	.077	.067	.061	.061	.061	.121
Potash extracted by acids	.196	.238	.142	.236	1.097	.363	.550	.429	.371	.382	.357
Soda extracted by acids	.112	.143	not est.	not est.	not est.	.165	not est.	.185	not est.	.123	.109
Water expelled at 380° F.	1.225	.865	.735	.420	.550	.600	.600	.580	.715	.565	.675
Sand and insoluble silicates	87.990	91.315	89.215	90.725	85.365	92.290	91.625	85.040	91.665	91.840	85.890
Total	100.070	100.407	99.636	99.986	100.486	100.359	100.306	100.466	100.406	100.414	100.536
Hygroscopic moisture	1.815	1.200	1.900	1.350	2.575	1.175	1.325	1.850	1.125	1.025	2.100
Potash in the insoluble silicates	1.654	1.619	2.036	1.672	1.755	1.121	1.127	1.278	1.274	1.457	1.573
Soda in the insoluble silicates	.775	.815	.570	.763	.608	.742	.714	.819	.846	.704	.611
Character of the soil	Virgin soil.	Old field	Subsoil.	Old field	Subsoil.	Virgin soil.	Old field	Subsoil.	Virgin soil.	Old field	Subsoil.

Although some of these soils contain more than the average proportion of sand and insoluble silicates, and a corresponding small proportion of alumina, &c., these are in such a state of fine division, being fine enough generally to pass through the fine sieve with 1600 meshes to the centimeter square, that this circumstance does not lessen their productiveness as much as might be supposed, while it gives them great permeability. Organic and volatile matters are also in small proportion in them, except in No. 2050, which has an average quantity; but this deficiency can be supplied by the use of barn-yard manure or by plowing under clover or other green crops. They all have more than the average of available potash, which, as well as their light and friable texture, no doubt adapts them to tobacco culture. No. 2154 has much more than the average proportion of this alkali. Their greatest apparent deficiency is of phosphoric acid, which, in Nos. 2152 and 2153 to 2159, inclusive, falls below the average normal proportion in good soils. This defect, however, may find an easy remedy in the application of phosphatic fertilizers, especially bone-dust or superphosphate, &c. The statement that soil No. 2153 is "considered worn out," finds no other apparent verification in the chemical analysis than this deficiency of phosphoric acid, which is also found in the other soils mentioned, except that its organic and volatile matters are in smaller proportions than in any of the other soils, and far below the average.

Notwithstanding these natural conditions, these soils, with good management, drainage where necessary, and the judicious use of fertilizers and a proper rotation of crops, can be made and kept quite productive.

HICKMAN COUNTY.

CLAYS.

No. 2161—"*Clay from chalk bluff, about two miles below Columbus.*" *Collected by John R. Procter.*

In moderately firm lumps, of a light buff and lead-grey color. Has a few ferruginous impressions of vegetable leaves. Seems to be quite sandy, yet is quite plastic and burns hard, and of a very light cream color. Refractory before the blow-pipe, only sintering a little.

On washing the air-dried clay with water, it left about sixty-nine per cent. of very fine sand, of a drab color, containing a few very small spangles of mica.

No. 2162—"*Clay from the bluffs at Columbus, upper part of the town. Will it make fire-brick?*" *Collected by John R. Procter.*

In somewhat friable lumps, of a very light-grey color; almost white; quite sandy. Very little ochreous stain visible. It is plastic, and burns hard, of a light cream color, and is refractory before the blow-pipe. The air-dried clay, washed in water, left 68.5 per cent. of fine sand of a light-grey color, nearly white, which is composed of very small, rounded grains of quartz, with a few small specks of mica.

COMPOSITION OF THESE HICKMAN COUNTY CLAYS, DRIED AT 212° F.

	No. 2161.	No. 2162.
Silica	76.360	84.918
Alumina	14.951	10.560
Iron peroxide	2.109	1.102
Lime	.325	.572
Magnesia	.173	.108
Potash	1.171	.651
Soda	.125	not est.
Combined water and loss	4.786	2.089
Total	100.000	100.000

No doubt No. 2162, if it will burn hard enough, would make quite refractory fire-brick, and it, as well as the other clay, might be made available for terra-cotta and other forms of pottery ware. No. 2161 is less refractory, because, doubtless, of its larger proportions of iron peroxide and potash.

Under the head of Ballard county, a comparison was made of the composition of one of these refractory clays and that of the celebrated glass-pot clay of Germany, and the main difference between them was in the larger proportion of potash in the Ballard county clay. The same similarity of composition with the glass-pot clay may be observed in some of

the Fulton county clays, as well as in the above described. Whether this somewhat greater proportion of potash would be fatal to the application of these refractory clays in the glass-works, is worthy of practical trial on a small scale.

No. 2163—"*Sand from Columbus; above the town. A very large deposit.*" *Collected by John R. Procter.*

A nearly white sand, made up mostly of small, rounded grains of hyaline quartz, colored very light purplish with iron oxide, and containing a few friable concretions made by infiltration of carbonate of lime.

Washed in water, air-dried, it left 99.40 per cent. of nearly pure white sand. It is no doubt pure enough for the manufacture of any but the very finest kind of glass.

No. 2164—"SOIL, LABELED "*New soil; surface soil; two years in cultivation in corn. Thought to be the prevailing upland soil in the county.*" *Collected by John R. Procter.*

In friable clods of a grey umber-brown color. It all passed through the coarse sieve, and its silicious residue left on the bolting-cloth sieve only two or three small particles of partly-decomposed silicates.

COMPOSITION, DRIED AT 212° F.

Organic and volatile matters	4.140
Alumina and iron and manganese oxides	3.694
Lime carbonate	.495
Magnesia	.232
Phosphoric acid	.156
Potash extracted by acids	.182
Soda extracted by acids	.564
Water expelled at 380° F.	1.010
Sand and insoluble silicates	90.095
Total	100.568
Hygroscopic moisture	1.735
Potash in the insoluble silicates	1.899
Soda in the insoluble silicates	.573

Although the proportion of sand and insoluble silicates is larger than the average, this is a very good soil, containing full average quantities of alkalies, phosphoric acid, and lime. Like most of our Kentucky soils, the silicious constituent is in such a fine state of division that it has many of the physical properties of fine clay, and would not, in ordinary parlance, be denominated sand.

JEFFERSON COUNTY.

CLAYS.

No. 2165—"*Shaly clay (or clay shale) in the limestone layers of the 'Cincinnati Group.' Lower Silurian. Jeffersontown.*" *Collected by Rev. H. Hertzer.*

A friable shale, generally of a lilac-grey color, but with some whitish portions. When powdered, it is quite plastic with water. It calcines of a light brick color; but before the blow-pipe it fuses into a dark-colored slag.

No. 2166—"*Shaly clay, of the Keokuk Group, from Cox's Knob. Jefferson county.*" *Collected by Rev. H. Hertzer.*

Generally of an olive-grey color. This also is quite plastic when powdered. It calcines of a very light brick color. Before the blow-pipe it fuses into a dark-colored slag.

No. 2167—"*Shaly clay (or clay shale) of the Keokuk Group. From the old Deposit Station. Jefferson county.*" *Collected by Rev. H. Hertzer.*

A friable shale or indurated clay of a light buff-grey color, with ferruginous stains between some of the laminæ.

Quite plastic when powdered. It burns of a light brick color, and fuses before the blow-pipe into a dark-colored slag.

COMPOSITION OF THESE SHALY CLAYS, DRIED AT 212° F.

	No. 2165.	No. 2166.	No. 2167.
Silica	47.960	58.840	61.900
Alumina with phosphoric acid	21.340	19.940	18.520
Iron peroxide	6.600	6.000	6.220
Lime	5.824	3.226	.123
Magnesia	3.524	.857	1.259
Potash	5.264	4.490	4.867
Soda	.250	.685	.612
Carbonic acid, undetermined, and water	9.238	5.962	6.499
Total	100.000	100.000	100.000

These indurated or shaly and marly clays, usually containing a notable proportion of the alkalies, potash and soda, as well as of lime and magnesia, with a variable small quantity of phosphoric acid, might, in some cases, be profitably applied as top-dressing to light soils which are deficient in clay, and which have become exhausted by culture. They could also be used for terra-cotta work, especially those which burn hard and of a handsome color. These might also be used for drain-tiles, flower-pots, and other forms of pottery. At a very high temperature, in the kiln, however, they would soften or melt.

MADISON COUNTY.

CLAYS.

No. 2168—"*Clay; Milton Barlow; from near Bybeetown. Bed four feet thick; in Black shale.*" *Collected by John R. Procter.*

Clay of a light, warm drab-grey color. Irregularly and imperfectly laminated. Quite plastic. Burns of a delicate light, reddish-cream color; nearly white. Before the blow-pipe it fuses into a whitish slag with difficulty.

No. 2169—"*Clay of workable thickness; on the road leading from Waco to R. Oldham's, about a mile and a half from Waco. Probably below the Corniferous limestone.*" *Collected by John R. Procter.*

A compact clay, generally of a light, olive-grey color, stained irregularly with ochreous and ferruginous. Quite plastic. Calcines quite hard, of a handsome light brick color. Before the blow-pipe it fuses into a brownish-grey slag.

No. 2170—"*Indurated clay; farm of C. L. Searcy, near Elliston. Beneath the Corniferous limestone. Bed ten feet thick or more. Makes a good soil.*" *Collected by John R. Procter.*

A light, olive-grey, laminated clay; mottled with ochreous or orange-colored ferruginous infiltrations. The laminæ are contorted. It is quite plastic. Burns of a handsome flesh-color. Fuses into a grey slag before the blow-pipe.

COMPOSITION OF THESE MADISON COUNTY CLAYS, DRIED AT 212° F.

	No. 2168.	No. 2169.	No. 2170.
Silica	62.560	64.566	62.580
Alumina	24.780	20.160	22.940
Iron peroxide	1.800	4.200	3.760
Lime	a trace.	.213	.560
Magnesia	.317	.641	.4[illegible]5
Potash	3.276	5.054	5.280
Soda	.294	not est.	.303
Combined water, &c., and loss	6.973	5.166	4.147
Total	100.000	100.000	100.000

These are good plastic clays for the manufacture of ordinary pottery ware, as well as for ornamental articles of terra-cotta, for which use they are adapted because of the pleasant tints they assume in calcination. They owe these tints to their considerable proportion of iron oxide, which, together with their large proportion of potash, renders them unavailable as fire-clays. This very circumstance, however, may fit them for stone-ware, and for superior kinds of hard, burnt, semi-fused, ornamental pottery in the hands of skillful workmen and artists.

MARLY SHALES OF MADISON COUNTY.

No. 2186—"*Marly shale; on the road near A. Lake's place; Drowning creek. 'Niagara Group.'*" *Collected by John R. Procter.*

An olive-grey and brownish-grey, somewhat firm shale, mottled in parts; adhering to the tongue. Quite plastic with water when powdered. Calcines of a light brick color. Fuses before the blow-pipe into a dark brown, nearly black slag.

No. 2187—"*Marly shale or indurated marly clay. On the hill two hundred yards north of Dr. Freeman's house. Probably the same bed as No. 2167, beneath the Corniferous limestone. The bed is six feet thick or more, and contains gypsum.*" *Collected by John R. Procter.*

Generally in thin, soft, irregular laminæ, of a light olive-grey color, irregularly varied with brownish yellow or ochre-

ous. It contains gypsum in irregular crystals between some of the laminæ; shows some fossil vegetable impressions, probably fucoid, on some of the layers.

It is quite plastic with water. Burns quite hard, of a handsome light brick color. Before the blow-pipe it melts into a dark brownish-green slag.

COMPOSITION OF THESE MARLY SHALES, DRIED AT 212° F.

	No. 2186.	No. 2187.
Silica	42.300	48.780
Alumina, &c.	20.840	17.320
Iron peroxide	4.120	3.240
Lime sulphate (gypsum)	. . . . .	19.285
Lime	13.320	. . . . .
Magnesia	.461	.496
Potash	2.387	4.768
Soda	.351	.240
Combined water, carbonic acid, and loss	16.221	5.871
Total	100.000	100.000

Because of the large proportion of gypsum (plaster of Paris) contained in No. 2187, and its considerable quantity of potash, it would no doubt prove a valuable top-dressing on soil and crops where the use of plaster is indicated. The shale No. 2186 would be useful on soils principally on account of the lime which it contains, which is equivalent to nearly twenty-four per cent of carbonate of lime.

No. 2188—A. "*Rock impregnated with Epsom salt, &c. C. L. Searcy's farm, near Elliston. Beneath the Corniferous limestone.*" *Collected by John R. Procter.*

A somewhat friable ferruginous sandstone, generally of a dull brown color, variegated somewhat with other tints. Showing minute crystalline specks in the cracks, and between the irregular laminæ. It contains irregular nodules of chert, infiltrated with bright iron pyrites.

B. Brown powder contained in the sample. Supposed to be the result of the disintegration of the rock by the crystalline force of the included salt.

The rock (A), when lixiviated with water, gave a solution which left, on evaporation and drying at the temperature of boiling water, as much as 4.8126 per cent. of the rock of *saline matters*, principally magnesia sulphate (Epsom salt), with small quantities of salts of lime, potash, soda, and iron.

The brown powder (B) was found to contain only 3.840 per cent. of *saline matters*, of similar composition. The rock was not submitted to analysis, but it is pretty evident that the Epsom salt and other sulphates were derived from the reaction of the oxidated iron pyrites on the bases contained in the rock.

LIMESTONES OF MADISON COUNTY.

No. 2189—"*Shelly limestone in the bed of Muddy creek; below J. Q. Compton's. 'Cumberland' shales? Probably Clinton.*" *Collected by John R. Procter.*

Of a dark umber-grey color. Generally quite friable; some portions are compact.

No. 2190—"*Impure limestone; top of the 'Cumberland' shales. Upper twelve inches. From below the mill-dam on Muddy creek, Elliston.*" *Collected by John R. Procter.*

A pretty firm, fine granular, or compact rock, of a handsome light olive-grey color.

No. 2191—"*Impure limestone. Top of 'Cumberland' shales. From eighteen to thirty inches below the massive bluff limestone of the Upper Silurian on Muddy creek.*" *Collected by John R. Procter.*

Rather darker colored than the next preceding; color inclined to brownish; not so hard as that. It contains no bitumen, but some sulphur.

No. 2192—"*Impure limestone; resting on the top of the 'Cumberland' shales; bottom stratum. From below the mill-dam on Muddy creek.*" *Collected by Jno. R. Procter.*

A granular limestone; somewhat cellular; containing some petroleum, which gives it a brownish color. It weathers ochreous.

No. 2193—"*Impure limestone. Niagara. Top stratum, eight inches thick. From below the mill-dam on Muddy creek. Elliston.*" *Collected by John R. Procter.*

An impure granular limestone; somewhat cellular; dark brownish-grey, somewhat mottled. Contains petroleum, the infiltration of which gave the dark color to the rock. When heated over the spirit-lamp, the petroleum exudes from it. It weathers ferruginous.

No. 2194—"*Impure limestone. Second from the top. From just below the mill-dam on Muddy creek. Elliston.*" *Collected by John R. Procter.*

It resembles the preceding, but is darker colored; it also contains petroleum and some iron pyrites.

No. 2195—"*Impure limestone. Niagara. Third stratum from the top. From below the mill-dam, Muddy creek. Elliston.*" *Collected by John R. Procter.*

Resembles the preceding; rather finer-grained and harder; also containing petroleum. Exterior surface weathered ferruginous.

No. 2196—"*Impure limestone. Clinton Group? From the quarry north of Rogersville. This rock makes good soil.*" *Collected by John R. Procter.*

A compact or fine granular rock; non-fossiliferous; of an olive-grey color; in some parts brownish. Not adhering to the tongue. It contains no petroleum, but some pyrites.

No. 2197—"*Limestone from below the Cauda-galli grit, at the base of the Corniferous limestone.*" *Collected by John R. Procter.*

A fine granular, brownish-grey rock. It gives the odor of petroleum when heated, and probably owes its brownish tint to a small quantity of this substance.

No. 2198—"*Bituminous limestone from above the Corniferous limestone; three to ten feet thick; from near Elliston.*" *Collected by John R. Procter.*

Generally of a dull, brownish black, or grey-black color. Some pieces with bands of a lighter grey tint. It is a fine granular rock.

No. 2199—"*Impure limestones. Top of the Corniferous limestone. Total thickness fifteen feet; with intercalated beds of purer limestone six inches thick.*" *Collected by John R. Procter.*

A tough, fine granular or compact rock. Samples from different levels are mixed; some of which are brownish-black, some umber colored, and some intermediate in tint.

No. 2200—"*Limestone; on the road one mile south of Mrs. S. J. Embry's; intercalated with the so-called Black Band, or bituminous limestone. To be tested for hydraulic properties.*" *Collected by John R. Procter.*

A dull buff-grey, fine granular rock, with some little infiltration of hydrated iron oxide.

COMPOSITION OF THESE MADISON COUNTY LIMESTONES, DRIED AT 212° F.

	No. 2189	No. 2190	No. 2191	No. 2192	No. 2193	No. 2194	No. 2195	No. 2196	No. 2197	No. 2198	No. 2199	No. 2200
Lime carbonate	48.530	37.760	33.560	45.700	50.860	50.960	51.200	35.160	43.060	41.150	36.580	47.580
Magnesia carbonate	11.790	10.050	6.855	27.475	20.100	27.972	25.124	4.646	9.994	13.908	18.541	17.133
Alumina }		17.656	21.256 }	11.360	9.960	5.960	12.360	10.706 }	9.420	9.040	4.010 }	
Phosphoric acid }	10.330	.204	.204 }				.140	.754 }				10.980
Iron peroxide }		3.700	4.120	3.500*	3.900	3.556	4.460	2.060	2.640	1.890	1.540 }	
Iron sulphide	....	....	....	....	....	.576	....	....	....	....	....	....
Potash	1.696	.458	.578	.501	.276	.276	.287	2.033	.770 }			
Soda	.347	.090	.045	.088	.054	.087	.049	.586	.149 }	13.022	7.339	not est.
Bitumen, water, and loss,	....	....	....	1.396	10.870	6.493	2.460	....	11.287 }			
Water and loss	6.567	4.902	4.302	....	....	....	....	4.275	....	....	....	6.117
Silicious residue	20.740	25.180	29.080	9.980	3.980	4.120	3.920	39.780	22.680	20.990	31.990	18.190
Total	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000
Percentage of lime	27.173	21.145	18.794	25.592	28.480	28.538	28.672	19.689	24.113	23.044	20.485	26.645
Percentage of magnesia	5.614	4.785	3.251	13.083	9.608	13.319	11.899	2.212	4.756	6.384	8.781	8.158
Percentage of silica	not est.	20.980	22.800	not est.	not est.	not est.	not est.	not est.	not est.	not est.	not est.	not est.

* Mostly Ferrous oxide in the rock.

These impure limestones vary considerably in their composition and properties. Nos. 2192, 2193, 2194, and 2195, from the Upper Silurian strata, are quite magnesian, and contain considerable proportions of alumina and iron oxide, with but a moderate quantity of silicious matter. Many of these magnesian limestones make quite good and durable building stone; but this depends greatly on the mechanical structure of the rock. The magnesian limestones also make good quicklime when pure, and when silicious or containing much clay, frequently prove to be good water-limes. A very imperfect trial of No. 2195, by calcining a small quantity, proved that it would harden in contact with water; but whether it would become very hard by time, or prove durable, was not ascertained. Possibly greater care in the experiment, in the burning, &c., with more time, would give a more satisfactory result. Its proportion of silica, however, is quite small.

The rest of these limestones were not tried in this relation, except Nos. 2189, 2190, and 2200, and these did not harden in a satisfactory manner in water. As all of these contain quite a large proportion of aluminous and silicious matters, if they would make water cement at all, it would be of the slowly-setting variety, like the artificial Portland cement, for the manufacture of which, with or without the addition of more lime, they might possibly be made available.

Specimens of Corniferous and Silurian limestones, showing bright olive-green blotches, specks, and grains, were sent to the laboratory to ascertain their nature. This green material, frequently found in a granular form, is the mineral glauconite, the main constituent of the green sand of the cretaceous formation, described in a previous chemical report under the number 2067.

IRON ORES FROM MADISON COUNTY—BOG IRON ORES.

No. 2201—"*Bog ore from near R. Dudley's, half a mile south of the Richmond and Irvine Turnpike. A thick deposit, on the Black Shale formation.*" *Collected by John R. Procter.*

Mostly soft ochreous material of different light tints, mixed

irregularly with some curved laminæ of more compact, dark colored limonite.

No. 2202—"*Bog ore; Black Shale formation; on the lands of T. P. Estill and M. T. Todd. Two hundred yards south of the Richmond and Irvine Turnpike, near Ross' blacksmith shop. Bed of workable thickness.*" *Collected by John R. Procter.*

Resembles the preceding, but is somewhat darker colored, and has more of the hard, irregular limonite layers.

No. 2203—"*Bog ore; on the Black Shale formation; a good deposit. Near Mrs. Tudor's, on the Richmond and Irvine Turnpike.*" *Collected by John R. Procter.*

Resembles the preceding. The samples are from different outcrops of the same bed, which seems to have considerable extent.

No. 2204—"*Bog ore; a thick deposit on the road to Red river, near T. Lewis', half a mile west of Harris' ferry, one mile from Kentucky river. Resting on Corniferous.*" *Collected by John R. Procter.*

Generally of a dull black color, like earthy manganese peroxide, with some little reddish and yellowish ochreous material intermixed.

COMPOSITION OF THESE BOG ORES, DRIED AT 212° F.

	No. 2201.	No. 2202.	No. 2203.	No. 2204.
Iron peroxide	28.440	19.800	30.870	17.300
Alumina and phosphoric acid	5.240	9.880	11.560	14.820
Lime carbonate	.190	.380	.290	.130
Magnesia carbonate	1.279	1.844	.897	1.041
Silicious residue	56.220	62.290	49.980	56.260
Water, alkalies, &c., and loss	8.631	5.806	6.403	10.449
Total	100.000	100.000	100.000	100.000
Percentage of iron	19.890	13.860	21.570	12.110

Generally too poor to be profitably smelted by themselves for iron; although some of them might be used in mixture with richer ores, provided the phosphoric acid is not in too large proportion. The ore varies considerably in different parts of the bed, and in some localities it might, no doubt, yield material for cheap mineral paint.

No. 2205—"*Ferruginous shale. Labeled 'Black Band ore.' W. B. Combs' Knob. Resting on the top of the coal.*" *Collected by John R. Procter.*

A somewhat compact, ferruginous shale, of a dull brownish-black color, spangled with fine scales of mica. Weathers ferruginous.

COMPOSITION, DRIED AT 212° F.

Iron oxide	19.500, containing 13.650 per cent. of iron.
Alumina and phosphoric acid	16.360
Lime	trace.
Magnesia	trace.
Silicious residue	39.940, containing 32.300 per cent. of silica.
Bituminous matter, water, and loss.	24.200
Total	100.000

Too poor to be called an iron ore.

SOILS FROM MADISON COUNTY.

No. 2206—"*Top soil from the farm of J. G. Covington, Muddy creek. Probably Clinton shales, above the Cincinnati Group. Has been in cultivation for twenty-six years in corn, with but two crops of small grain. With an average yield all the time of sixty bushels of corn to the acre. Lies above the overflow.*" *Collected by John R. Procter.*

Dried soil of a brownish-umber color; pretty friable. It all passed through the coarse sieve except a small proportion of small ferruginous concretions, and some few small rounded pebbles of reddish quartz. The bolting-cloth separated from its silicious residue a small proportion of small rounded white quartz grains, and very few of partly-decomposed concretions.

No. 2207—"*Subsoil from the same field, taken one foot below the surface,*" &c., &c.

The dried subsoil is very slightly darker colored than the surface soil, and the clods are firmer. It all passed through

the coarse sieve except a small proportion of small ferruginous concretions, somewhat rounded. The bolting-cloth separated from its silicious residue a rather larger proportion of small, rounded white quartz grains than from the preceding, but very few grains of partly-decomposed concretions.

No. 2208—"*Bottom clay under the two preceding,*" &c., &c.

The dried under-clay is of a handsome brownish-yellow ochre color. It is in pretty firm clods. It all passed through the coarse sieve except a small proportion of small ferruginous concretions, and a few small white quartz pebbles. The bolting-cloth removed from its silicious residue a small proportion of small, rounded white quartz grains, and a few of partly-decomposed concretions; a smaller quantity than from the preceding.

COMPOSITION OF THESE MADISON COUNTY SOILS, DRIED AT 212° F.

	No 2206.	No. 2207.	No. 2208.
Organic and volatile matters	7.240	7.150	2.950
Alumina and iron and manganese oxides	10.353	10.905	11.032
Lime carbonate	2.485	1.870	.220
Magnesia	.989	.809	.160
Phosphoric acid	.387	.300	.173
Potash extracted by acids	.545	.638	.359
Soda extracted by acids	.162	. . . . .	. . . . .
Water expelled at 380° F.	1.122	1.450	.800
Sand and insoluble silicates	76.715	77.395	84.174
Total	99.998	100.5'7	99.868
Hygroscopic moisture	3.275	3.775	2.575
Potash in the insoluble silicates	1.949	2.079	1.800
Soda in the insoluble silicates	.206	.281	.407
Character of the soil	Cultivated field.	Subsoil.	Under-clay

The upper soil and subsoil present in their composition all the characteristics of very fertile soil. The under-clay is not so rich as these.

WATER FROM MADISON COUNTY.

No. 2209—"*Sulphur water from a spring on the farm of C. L. Searcy, Elliston. . In the Niagara Group.*" *Collected by John R. Procter.*

The water was brought to the laboratory in a jug and bottle, both well corked. It retained a slight odor of hydrogen sulphide, and was slightly opalescent from a light precipitate of sulphur. It had deposited a dark sediment, and the corks were slightly blackened, as from the presence of iron. Testing showed it to be slightly alkaline in reaction.

COMPOSITION OF SALINE CONTENTS OF THIS WATER, in 1000 PARTS.

Lime carbonate	0.2040	Held in solution by carbonic acid.
Magnesia carbonate	.0322	
Iron carbonate and phosphoric acid	.0172	
Silica	.0045	
Lime sulphate	.4301	Left dissolved in the water after long boiling.
Calcium chloride	.0124	
Magnesium chloride	.0920	
Potassium chloride	.0380	
Sodium chloride	.3221	
Soda carbonate	.0937	
Silica	.0018	
Lithium, strontium, and sodium sulphide	traces	
Organic matters and loss	.3294	
Total solid matters in 1000 parts of the water	1.5774	

The water also contained free carbonic acid, and, at the spring, no doubt, a notable amount of hydrogen sulphide; but the quantity of these gases could only be correctly estimated at the source. It seems to be a good saline sulphur water, containing a small quantity of iron, which would add to its medicinal utility.

No. 2210—"*Water from an Artesian well one hundred and twenty-six feet deep. Bored in the rocks of the Upper Cincinnati Group. About one hundred and fifty feet south of the railroad track at Clear Creek Station, and about two hundred and fifty feet west of Silver creek, in a bottom. The water stands in the well at thirty-five feet from the surface.*" *Sent by John R. Procter.*

On evaporation to dryness, this water left 0.4658 of a

gramme of saline matters, &c., dried at 212°, to the thousand of the water.

The *composition* of which saline matter is as follows:

Lime carbonate	0.1550	Held in solution by carbonic acid.
Magnesia carbonate	.0503	
Iron carbonate and silica	n. e.	
Lime sulphate	.0350	
Potash sulphate	.0124	
Soda sulphate	.0096	
Sodium chloride	.1467	
Silica	.0060	
Moisture and loss	.0508	
Total saline matters in 1000 parts of the water	0.4658	

This is what is called a "hard" water; but it contains no organic matters or other injurious ingredient. Its small proportion of sulphate of lime would only tend to form a hard crust in steam-boilers when it was used in them for too long a time without "blowing out."

The water of Silver creek was tested at the same time with the above described; also that of a well in the creek; both at the Silver Creek Distillery, Madison county.

The Silver creek water left, on evaporation, 0.1772 per 1000 of solid saline matters, slightly stained with organic matters.

The well water left 0.2212 per 1000 of the water of saline matters, which also showed a trace of organic matter. The composition appeared to be similar to that of the saline matter of the Artesian well water.

McCRACKEN COUNTY.

No. 2211—"*Fire-clay, three and three quarters miles south of Paducah, on the Mayfield road.*" *Collected by John R. Procter.*

In friable lumps, generally of a very light grey color, nearly white, mottled with a very light ochreous material.

It is quite plastic. Before the blow pipe it burnt hard, of a light grey color, nearly white, and finally fused with great difficulty.

COMPOSITION, DRIED AT 212° F.

Silica	64.480
Alumina with trace phosphoric acid	24.691
Iron peroxide	1.869
Lime	.448
Magnesia	.137
Potash	1.457
Soda	.083
Combined water and loss	6.835
Total	100.000

While this clay would answer well for the manufacture of ordinary fire-brick, and of rather superior varieties of pottery-ware, terra-cotta, &c., its considerable proportions of potash and iron peroxide might cause it to soften when exposed to a very intense heat.

No. 2212—"*Subsoil from land of Dr. S. B. Caldwell, two miles southwest of Paducah, McCracken county. This earth, when dug up and spread upon the land, produces good results. Quaternary.*" *Collected by John R. Procter.*

The dried soil is friable, and of a light brownish-grey color. The coarse sieve removed from it some friable shot iron ore, and a small silicious fragment. All its silicious residue passed through the bolting-cloth, except a very few small, rounded grains of hyaline quartz.

COMPOSITION OF THIS SUBSOIL, DRIED AT 212° F.

Organic and volatile matters	1.840	
Alumina and iron and manganese oxides	5.883	
Lime carbonate	.070	
Magnesia	.200	
Phosphoric acid	.082	
Potash extracted by acids	.186	
Soda extracted by acids	.314	
Water expelled at 380°	.485	Containing:
Sand and insoluble silicates	90.920	Potash=1.773
		Soda = .855
Total	99.980	
Hygroscopic moisture = 1.500 per cent.		

No reason appears in the chemical composition of this earth why it should act as a fertilizer, except when plentifully applied on poor light soils.

NELSON COUNTY.

SOILS.

No. 2213—"*Soil from a field on the farm of Mr. James R. Ballard, two miles northwest of Rohan's Knob. The field has not been wasted much by cultivation, but in washing away. Timber, mostly white oak and ash. Bed rock, black slate and Corniferous limestone.*" *Collected by John R. Procter.*

The dried soil is friable, and of a reddish, light brownish tint. The coarse sieve separated from it 1.5 per cent. of its weight of small, partly-rounded ferruginous fragments. Its silicious residue, from digestion in acids, all passed through the fine sieve (1,600 meshes to the centimeter square), except a small proportion of small particles of partly-decomposed concretions, and a few small grains of white quartz.

No. 2214—"*Subsoil of the next preceding, ten inches from the surface,*" *&c.*

The dried subsoil is lighter colored and more yellowish than the preceding. Of a light brick color. Its clods are quite firm. The coarse sieve separated from it only 0.5 per cent. of small ferruginous fragments, partly rounded. The fine sieve, with 1,600 meshes to the centimetre square, separated from its silicious residue a considerable proportion of small particles of partly-decomposed concretions, and only one or two small silicious grains.

No. 2215—"*Bottom soil or under-clay of the next preceding, two feet from the surface; not penetrated by roots.*" *Collected by John R. Procter.*

The dried soil is of a handsome light brownish orange-red color, or handsome light brick color. The coarse sieve separated from it 1 per cent. of small irregular quartz pebbles. The fine sieve removed from its silicious residue a small proportion of small particles of partly-decomposed concretions, and of rounded quartz grains, with a few minute silicified joints of encrinital stems.

COMPOSITION OF THESE NELSON COUNTY SOILS, DRIED AT 212° F.

	No. 2213.	No. 2214.	No. 2215.
Organic and volatile matters	3.360	2.990	3.300
Alumina and iron and manganese oxides	7.977	10.349	14.368
Lime carbonate	.270	.245	.880
Magnesia	.166	.187	.809
Phosphoric acid	.108	.061	.102
Potash extracted by acids	.116	.164	.361
Soda extracted by acids	.225	.045	.657
Water expelled at 380° F.	1.215	.900	2.415
Sand and insoluble silicates	86.650	85.075	76.840
Total	100.087	100.016	99.732
Hygroscopic moisture	1.485	2.525	1.129
Potash in the insoluble silicates	1.669	1.835	2.742
Soda in the insoluble silicates	.274	.400	.225
Percentage of gravel	1.400	.500	1.000
Character of the soil	Surface soil	Subsoil.	Under-clay

These soils are of good average fertility, judging from their chemical composition and physical constitution. The only apparent deficiency is of phosphoric acid in the subsoil No. 2214. This, however, is easily to be supplied in phosphatic fertilizers. The under-clay is chemically richer than the upper soil.

Some of the *silicious residue* of the "under-clay" was submitted to analysis by fusion with the alkaline carbonates, &c., with the following results, viz:

CONSTITUENTS OF ONE GRAMME OF THE *SILICIOUS RESIDUE* OF THE UNDER-CLAY, No. 2215, DRIED AT 212° F.

Silica	0.76880
Alumina and iron oxide, &c.	.18920
Lime	.00061
Magnesia	.00569
Phosphoric acid	.00051
Potash	.02742
Soda	.00225
Moisture and loss	.00552
Total	1.00000

This analysis shows that the silicious residue of this under-clay not only contains 2.742 per cent. of potash, but as much

as .05 per cent. of phosphoric acid, besides notable quantities of alumina, lime, and magnesia. Its gradual decomposition by weathering would undoubtedly tend to maintain the fertility of the soil. Under Fulton county the analyses of other silicious residues are reported which gave analogous results.

No. 2216—"*Marly clay at the base of Carboniferous series; probably on the Keokuk horizon. Part of the section contains thin beds of clay iron-stone; but beds of many feet in thickness can be obtained. Nelson county.*" *Collected by N. S. Shaler.*

This clay is quite plastic, when powdered, and calcines of a buff color. Before the blow-pipe it fuses into a dark colored slag.

COMPOSITION, DRIED AT 212° F.

Silica	61.100
Alumina with phosphoric acid	18.200
Iron peroxide	6.000
Lime	4.904
Magnesia	1.542
Potash	4.101
Soda	.821
Combined water, carbonic acid, and loss	3.332
Total	100.000

This clay may be employed for terra-cotta work or other pottery not to be exposed to a very high temperature in burning; but its large proportions of iron oxide, lime, potash, magnesia, and soda cause it to be readily fusible. Its proportion of phosphoric acid was not determined, but its other ingredients, mentioned above, especially the alkalies and lime, may make it a valuable marl for top-dressing light and exhausted soils.

PULASKI COUNTY.

SOILS.

No. 2217—"*Virgin soil from a ridge near the farm of Mr. Taylor, on the London and Somerset road. This ridge divides the waters of Sinking Valley creek. Geological position: one hundred and fifty feet above the Sub-carboniferous limestone, the ridge being formed of the coal-bearing sandstones and slates. Very thin poor land. Scarcely any one is willing to settle on this kind of ridges.*" *Collected by Joseph Lesley, jr., July,* 1859 (*during the former Survey under the late Dr. D. D. Owen*).

The dried soil is of a grey-buff color; friable. The coarse sieve removed from it 31.6 per cent. of irregular fragments of ferruginous sandstone. Only the fine soil, which passed through this sieve, constituting 68.4 per cent. of the whole soil, was taken for chemical analysis. The same practice obtained in all cases.

The silicious residue of this soil, left after digestion in acids, with a view to its analysis, all passed through the bolting-cloth, except a very few small particles of partly-decomposed concretions and of rounded quartz grains.

No. 2218—"*Virgin soil from a ridge dividing Rockcastle from Buck creek waters; Lick creek, Clifty creek, Whetstone creek, and a branch of Sinking creek, all heading in this immediate neighborhood. Geological position: upper part of the coal-bearing sandstones and shales. This ridge extends twenty to twenty-five miles in a southerly direction.*" *Collected by Jos. Lesley, jr., June,* 1859.

The dried soil is of a brownish grey-buff color. It contains few clods, which are quite friable. The coarse sieve separated from it 9.2 per cent. of irregular fragments of ferruginous sandstone, scarcely at all rounded. All its silicious residue passed through the bolting-cloth, except two or three small particles of partly-decomposed concretions, and a few small rounded grains of white quartz.

No. 2219—"*Surface soil from a field now* (1859) *in corn, adjoining the location of the next preceding. It has been cleared eight years. Will produce twenty-five bushels of corn to the acre. Alternation of crops has been attended to.*" *Collected by Jos. Lesley, jr.*

The dried soil is friable, darker colored than the preceding; of a light umber tint. The coarse sieve separated from it 19.2 per cent. of irregular, somewhat rounded fragments of ferruginous sandstone. From its silicious residue the bolting-cloth separated a little more of small, rounded particles of white quartz than from the preceding, but very few of partly-decomposed concretions.

No. 2220—"*Subsoil of the next preceding,*" *&c., &c.*

The dried subsoil is of a light brownish or ferruginous grey tint, lighter in color than the preceding. It contains many fragments of rock. The coarse sieve separated 34.7 per cent. of irregular fragments of ferruginous sandstone. The bolting-cloth separated from the silicious residue rather more of small rounded quartz grains than from the preceding, and a few more of small particles of partly-decomposed concretions.

No. 2221—"*Virgin soil from the farm of Owen Hunt, two miles and a half east of Grundy; six miles northeast of Somerset; on Blazed Hollow branch of Pitman's creek. Geological position: slopes formed of Sub-carboniferous limestone.*" *Collected by Joseph Lesley, jr.*

The dried soil is quite light and friable, of a light brownish-grey color. The coarse sieve removed from it 13.8 per cent. of small, rounded quartz pebbles, with a few of small scarcely-rounded fragments of ferruginous sandstone. Its silicious residue, after digestion in acids, left on the bolting-cloth a rather larger proportion of small, rounded grains of whitish and reddish quartz than the preceding soils, also a few particles of partly-decomposed concretions.

No. 2222—"*Surface soil from a field adjoining the locality of the next preceding, which has been in cultivation about seventy-five years; in crops alternating with corn, wheat, and oats; now (June, 1859) in corn, which will yield about thirty bushels to the acre. Cattle have been turned on sparingly. Has been plowed deep for Eastern Kentucky, to the depth of eight to nine inches.*" *Collected by Joseph Lesley, jr.*

The dried soil is of a dark brownish-grey color, darker than the preceding. Friable. The coarse sieve removed from it 15 per cent. of small quartz pebbles and sandstone fragments; the pebbles not being so large proportion as in the preceding soil. The bolting-cloth separated from its silicious residue about the same proportion of small rounded grains of whitish and reddish quartz, and of partly-decomposed concretions, as from the preceding.

No. 2223—"*Subsoil of the next preceding,*" *&c., &c.*

The dried subsoil is of a lighter brownish-grey than the preceding. Contains moderately firm clods.

The coarse sieve separated only 3.1 per cent. of small somewhat rounded fragments of ferruginous sandstone mixed with a very few small quartz pebbles. All its silicious residue passed through the bolting-cloth, except a rather small quantity of fine white sand, and rather more of small particles of partly-decomposed concretions than from the preceding.

No. 2224—"*Under-clay taken from below the next preceding to show the clayey nature of the real under-soil of these limestone valleys. Sample taken from the depth of twelve to fifteen inches.*" *Collected by Jos. Lesley, jr.*

This dried under-clay is of a light brownish-ochre color. The clods are quite firm. The coarse sieve separated from it 4.5 per cent., mostly of small quartz pebbles. From its silicious residue the bolting-cloth removed a considerable proportion of small grains of partly-decomposed concretions and a few of reddish and whitish quartz.

No. 2225—"*Virgin soil from the farm of James Denny, on the border of Wayne county, seven miles south of Somerset, one mile from the forks of the main Cumberland and Big South Fork. Geological position: Sub-carboniferous limestone formation. Note: This is a characteristic soil of the 'Barrens' of Pulaski and Wayne counties. The 'Barrens' form a strip of the first great terrace above and south of the Cumberland river, averaging five miles in width and extending lengthwise from the forks of the Cumberland to and beyond Monticello. Fifty years ago they were open prairie, with only occasional high swells, covered with black oak timber; now they are covered, where not cultivated, with a fine 'second growth,' mostly of black oak and hickory, with scattering dogwood and black gum.*" *Collected by Joseph Lesley, jr.*

The dried soil is friable, of an umber-grey color. The coarse sieve removed from it 8 per cent. of angular cherty particles, mixed with a little shot iron ore. All of its silicious residue passed through the bolting-cloth except a small proportion of hard, irregular particles of partly-decomposed concretions, and a small quantity of small, rounded grains of white quartz.

No. 2226—"*Surface soil from a field adjoining the locality of the next preceding. This field has been cleared up three years, and been planted in corn each year; plowed shallow; no manure used.*" *Collected by Joseph Lesley, jr.*

The dried soil is friable, of a light chocolate tint, deeper colored than the next preceding. The coarse sieve removed from it only 1.5 per cent. of cherty particles. Its silicious residue left on the bolting-cloth but a small proportion of small particles of partly-decomposed concretions and of small quartz grains.

No. 2227—"*Subsoil of the next preceding,*" *&c., &c.*

The dried subsoil contains some friable clods. It is of a slightly darker color than the next preceding. The coarse sieve removed but a very small proportion of small, cherty fragments.

From its silicious residue the bolting-cloth separated a considerable proportion of small, rounded particles of partly-decomposed concretions, mixed with a small quantity of small, rounded grains of white quartz.

No. 2228—"*Surface soil from another field adjoining the locality of No. 2225. This field has been in active cultivation for fifty to sixty years, with the exception of the last two years. It is now* (1859) *in pasture* (*viz: pennyroyal and crab grass*)." *Collected by Joseph Lesley, jr.*

The dried soil is friable, and of a light chocolate color. The coarse sieve removed from it but a very small proportion of shot iron ore, with a few small, cherty particles. The bolting-cloth separated from its silicious residue only a small proportion of small quartzose and silicate grains.

No. 2229—"*Subsoil of the next preceding,*" *&c., &c.*

The dried subsoil contains some friable clods. It is darker colored and more reddish than the preceding, being of a warm or reddish-brown color. The coarse sieve removed from it but a very small proportion of small, angular, cherty fragments and shot iron ore. From its silicious residue the bolting-cloth separated a considerable quantity of small, rounded particles of partly-decomposed concretions, mixed with a small proportion of small, rounded grains of white quartz.

A marked difference is observable in the rocky fragments or gravel of these different soils. In the "ridge" soils, Nos. 2217 to 2220, inclusive, these are generally angular fragments of ferruginous sandstone; in the Sub-carboniferous soils, Nos. 2221 to 2224, inclusive, the gravel is mainly quartzose pebbles, with but little of ferruginous sand rock or concretions; while in the "Barrens" soils, Nos. 2225 to 2229, inclusive, the gravel is cherty, and usually in angular fragments.

COMPOSITION OF THESE PULASKI COUNTY SOILS, DRIED AT 212° F.

	No. 2217	No. 2218	No. 2219	No. 2220	No. 2221	No. 2222	No. 2223	No. 2224	No. 2225	No. 2226	No 2227	No. 2228	No. 2229
Organic and volatile matters	3.890	4.200	6.375	3.260	2.135	2.550	2.140	2.225	4.590	5.615	3.790	4.300	3.700
Alumina and iron and manganese oxides.	5.661	5.640	6.726	7.894	4.090	5.109	6.240	7.767	4.938	7.072	7.847	8.282	8.923
Lime carbonate	.125	.095	.345	.095	.170	.245	.170	.195	.220	.295	.130	.310	.220
Magnesia	.088	.070	.124	124	.052	.097	.128	.213	.115	146	.122	.115	.115
Phosphoric acid	.089	.045	.059	.076	.045	.076	.045	.083	.087	.118	.093	.148	.077
Potash extracted by acids	.345	.222	.277	.066	.147	.151	.217	.351	.145	100	.213	.149	.149
Soda extracted by acids	.027	. . . . .	.139	.256	.071	.060	.083	. . . . .	.089	.084	. . . . .	. . . . .	. . . . .
Water expelled at 380° F	.925	1.000	1.425	.790	.525	.650	.560	.525	1.535	1.985	1.400	1.700	1.550
Sand and insoluble silicates	88.690	88.765	84 350	87.640	92.765	91.240	90.540	88.790	88.340	84.500	86.675	84.990	85.490
Total	99.840	100.037	99.820	100.201	100.000	100.178	100.123	100.149	100.059	99.915	100.270	99.994	100.224
Hygroscopic moisture	0.915	1.315	1.900	1.235	2.135	0.900	0.965	0.775	1.750	1.525	1.200	1.225	1.340
Potash in the insoluble silicates	.642	.927	.852	.878	.778	.967	1.047	1.237	.953	.863	.762	.826	.795
Soda in the insoluble silicates	.205	.287	.139	.220	.260	.349	.340	.289	.223	.199	.230	.167	.160
Percentage of gravel, &c., in the soil	31.600	9.200	19.200	34.700	13.800	15.000	3.100	4.500	8.000	1.500	Sma'l p'n	Small p n.	Small p'n.
Character of the soil	Virgin soil	Virgin soil	Cultivated field.	Subsoil.	Virgin soil	Old field soil.	Subsoil.	Under-clay.	Virgin soil	Cultivated field.	Subsoil.	Old field soil.	Subsoil.

When we discount the ridge soil, No. 2217, by the 31.60 per cent. of sandstone fragments which it contains, and which could hardly afford much vegetable nourishment, we see that it cannot be a very durable and productive soil, yet if its local situation were favorable to the cultivation of crops, it might be made durable and profitably fertile with skillful management and the use of fertilizers. The principal deficiency in the fine earth of these soils seems to be of phosphoric acid. Subsoil No. 2220 not only contains a very large proportion of the rocky gravel, 34.70 per cent., but is also deficient in phosphoric acid and available potash. It would not benefit the surface soil to throw up this subsoil. The proportion of alkalies in the insoluble silicates seems to be below the general average of good soils.

Soils No. 2221, 2222, and 2223 also contain but a small proportion of phosphoric acid, but have a larger quantity of potash. Their sand and insoluble silicates are in large proportion. The soils from the "Barrens" are richer than these others, and ought to be quite productive under good management. These subsoils seem to be somewhat deficient in phosphoric acid, which is in good average proportion in the surface soils.

ROCKCASTLE COUNTY.

SOILS.

No. 2230—"*Virgin soil from the nose of the ridge between the East and West Forks of Skeggs' creek, and from the land of Halbert McClure. Geological position: coal-bearing sandstones and shales, one hundred feet above the Sub-carboniferous limestone, from a terrace containing coal.*" *Collected by Jos. Lesley, jr., June,* 1859.

The dried soil is light and friable. It is of a light chocolate yellowish-grey color. The coarse sieve separated from it 14.5 per cent. of small irregular somewhat rounded fragments of soft ferruginous sandstone. All its silicious residue, from digestion in acids, passed through the bolting-cloth, except a very few small grains of partly-decomposed concretions and a few small rounded quartz grains.

No. 2231—"*Virgin soil from a ridge in the northeast corner of Rockcastle county, which divides the waters of Clear and Brush creeks; both tributaries to Roundstone creek. Timber: chestnut oak and white oak, with undergrowth of laurel and some pine. Geological position: Millstone grit, which, on this ridge and on parallel ones in this part of the country, forms the capping.*" *Collected by Joseph Lesley, jr.*

The dried soil is of a grey-buff color; it is quite friable. The coarse sieve separated 21.4 per cent. of irregular fragments of ferruginous sandstone and some small, rounded pebbles of white quartz. The bolting-cloth removed very few small grains of partly-decomposed concretions from its sand and insoluble silicates left after digestion in acids, but a pretty large proportion, about one sixth of the whole, of small, rounded white quartz grains.

No. 2232—"*Virgin soil from the farm of William M. Smith, on the Crab Orchard and London Turnpike, three miles east of Mount Vernon. Taylor's branch of Roundstone creek runs through the field. Geological position: slopes of the Sub-carboniferous limestone. These slopes form the principal part of the farmed land on Roundstone, Skegg's, and Line creeks and their tributaries in this part of Rockcastle county. The northern slopes of the valleys are considered the best.*" *Collected by Joseph Lesley, jr.*

The dried soil is darker colored than the preceding. It is of a brownish grey-buff color. Its clods are friable. The coarse sieve removed from it 12.5 per cent. of irregular, somewhat rounded fragments of ferruginous sandstone. The bolting-cloth separated from its silicious residue but a small proportion of small particles of partly-decomposed concretions and of fine, rounded grains of white and reddish quartz.

No. 2233—"*Surface soil from a field adjoining the next preceding. This field was cleared up thirty years ago, and is now (1859) in oats. It was supposed to be worn out when Mr. Smith took it; has been manured, and now yields fifty bushels of corn per acre.*" *Collected by Joseph Lesley, jr.*

The dried soil is darker colored and more brownish than the next preceding. Its clods are friable. The coarse sieve removed from it 17.4 per cent. of irregular fragments, somewhat rounded, of soft ferruginous sandstone. Its sand and insoluble silicates all passed through the bolting-cloth except a very small proportion of small grains of partly-decomposed concretions and of white quartz.

No. 2234—"*Subsoil of the next preceding*," *&c.*, *&c.*

The dried subsoil resembles the next preceding soil, but is a little darker colored, and its clods are quite firm. The coarse sieve removed from it 12 per cent. of irregular fragments, somewhat rounded, of soft, ferruginous sandstone. The bolting-cloth separated rather more of small, rounded grains of white quartz from its silicious residue than from the preceding, but very few small grains of partly-decomposed concretions.

No. 2235—"*Surface soil of a field in pasture adjoining No. 2233. This field has been cleared up sixty years, and only manured on the very bare spots.*" *Collected by Joseph Lesley, jr.*

The dried soil is of a very light chocolate tint, but somewhat darker in color than the next preceding. The coarse sieve separated from it 29 per cent. of irregular fragments of soft ferruginous sandstone. Its silicious residue all passed through the bolting-cloth, except a few small, soft grains of partly-dissolved concretions, and a very small proportion of small, rounded white quartz grains.

No. 2236—"*Subsoil of the next preceding*," *&c.*, *&c.*

The dried subsoil resembles No. 2232. The coarse sieve removed 28.6 per cent. of irregular fragments of soft ferruginous sandstone, with some fragments of limonite, and a few quartzose pebbles. All its silicious residue passed through the bolting-cloth, except a small proportion of grains of partly-decomposed concretions, and of white quartz.

COMPOSITION OF THESE ROCKCASTLE COUNTY SOILS, DRIED AT 212° F.

	No. 2230	No. 2231	No. 2232	No. 2233	No. 2234	No. 2235	No. 2236
Organic and volatile matters	6.890	4.150	4.950	6.065	4.265	4.500	3.360
Alumina & iron & manganese oxides	7.126	3.877	7.342	8.565	8.490	7.097	7.625
Lime carbonate	.345	.085	.435	.640	.625	.495	.395
Magnesia	.223	.120	.232	.153	.175	.130	.187
Phosphoric acid	.109	.083	.093	.146	.220	.173	.125
Potash extracted by acids	.366	.100	.231	.339	.453	.208	.254
Soda extracted by acids	.093	. . . . .	.008	. . . . .	.125	.002	.051
Water expelled at 380° F.	1.925	.750	1.300	1.650	1.375	1.300	.965
Sand and insoluble silicates	82.690	90.665	85.065	82.040	83.890	85.980	87.690
Total	99.767	99.830	99.656	99.598	99.618	99.885	100 032
Hygroscopic moisture	2.085	0.900	1.775	2.225	1.915	1.510	1.250
Potash in the insoluble silicates	.925	.671	.918	.815	.857	.756	.690
Soda in the insoluble silicates	.128	201	.312	.248	.260	.250	.234
Percentage of gravel, &c.	14.500	21.400	12.500	17 400	12.000	29.000	28.600
Character of the soil	Virgin soil	Virgin soil	Virgin soil	Old field	Subsoil.	Old field	Subsoil.

Of the above described soils of Rockcastle county, No. 2230, based on the coal-measure shales, &c., is quite a good soil; to be discounted, however, by its 14.5 per cent. of ferruginous sandstone fragments or gravel. No. 2231, situated on the Millstone grit, is the poorest of the whole, especially as it contains 21.4 per cent. of this gravel. The other soils described, all based on the Sub-carboniferous limestone formation, are better than the average of good soils; but are also to be discounted by their considerable percentage of sandstone gravel, of which the soil of the old field, No. 2235, and its subsoil, show much the largest proportions. In these old field soils may also be seen the usual results of long cultivation in the diminution of the alkalies, phosphoric acid, &c., as compared with the original virgin soil of the neighborhood. Such a comparison could not be accurately made unless the two soils were similarly located in relation to the action of the atmospheric waters; those on a slope being more subject to their deteriorating, washing influence than those on more level ground. This influence may probably be observed on the relative composition of soil No. 2232 situated on the slopes of Roundstone. The old field soil, No. 2233, is now quite rich.

TRIMBLE COUNTY.

No. 2237—"*A 'chalky substance' sent by Mr. S. E. Hampton for examination.*"

According to his report, it exists in a stratum about two feet thick, discovered in digging a cistern about five feet below the surface, in a mound-like hill, the highest in the neighborhood, which is in Hunter's Bottom, about five miles below Carrollton.

It is a fine granular rock, soft enough to be scratched by the nail, nearly white, with a very faint yellowish tint. Under the microscope it was seen to be made up of minute, transparent crystals, in form somewhat like those of Aragonite. By tests it was found to be nearly pure carbonate of lime, with a trace of iron oxide.

If in large quantity, as it is said to be by Wm. Hampton, it might be utilized in the manufacture of soda ash from salt, or of glass, or it might be made valuable as an ingredient in the manufacture of Portland cement.

No. 2238—"*By the same person a sample of another white substance was sent, labeled 'Silicious clay,' forty feet thick and a mile wide, from near Milton, Trimble county.*"

Quite a friable concretion, which was found to be nearly pure quartz, with a minute quantity of carbonate of lime. The microscope shows it to be in the form of very minute, transparent, colorless, acicular, prismatic crystals.

This pure silicious deposit, which, like the preceding one of carbonate of lime, is doubtless of more recent deposit than rocky substratum, might be made profitable in the manufacture of glass, of pottery ware, of Portland cement, soluble glass, &c.

WAYNE COUNTY.

SOILS.

No. 2239—"*Virgin soil from the farm of Silas Hansford, in the northeast end of Wayne county, on the Dry Branch of Big Sinking creek, three miles due west from its mouth. This sample is from a piece of woods back of his house. Geological position: upper part of the Sub-carboniferous limestone, on a terrace which has received more or less of the débris from the sandstones and shales lying immediately above it.*" *Collected by Joseph Lesley, jr.*

The dried soil is friable, and of a light greyish-umber color. The coarse sieve separated from it 7.5 per cent. of fragments

of ferruginous sandstone, not much rounded. All of its silicious residue, from digestion in acids, passed through the bolting-cloth, except a small proportion of small, rounded, soft particles of partly-decomposed concretions, and of whitish and reddish quartz.

No. 2240—"*Surface soil from a field next adjoining to the location of the next preceding, which has been cleared two years. Last year it was in turnips; this year* (1859) *is in corn.*" *Collected by Joseph Lesley, jr.*

This dried soil resembles the preceding. The coarse sieve separated from it 4.4 per cent. of small, slightly-rounded ferruginous sandstone particles. Its silicious residue all passed through the bolting-cloth except a small proportion of small, rounded grains of white quartz, and of partly-decomposed concretions.

No. 2241—"*Subsoil of the next preceding,*" *&c., &c.*

The dried subsoil is rather lighter colored and more yellowish than the soil preceding. It contains some pretty firm clods. The coarse sieve separated from it 16.5 per cent. of irregular fragments, some pretty large, of ferruginous sandstone and concretions, some of which show much manganese oxide. The bolting-cloth removed from its silicious residue a smaller proportion of small grains of quartz, and of partly-decomposed concretions than from the preceding soils.

No. 2242—"*Virgin soil from farm of Silas Hansford, &c., &c. From below his house, in a dry, flat, swelling valley. Geological position: about the middle of the Sub-carboniferous limestone formation.*" *Collected by Joseph Lesley, jr.*

The dried soil is like No. 2239, slightly darker colored. It has some friable clods. The coarse sieve removed from it 6.6 per cent. of small, rounded, ferruginous silicious particles, and a few small quartz pebbles. From its silicious residue the bolting-cloth separated a little larger proportion of small, rounded friable particles of partly-decomposed concretions than from the preceding soil; also a small proportion of small, rounded white quartz grains.

No. 2243—"*Surface soil from a field across the road from the location of the next preceding soil. This field has been in active cultivation for fifty years; mostly in corn; is this year* (1859) *in corn. No manure has been used.*" *Collected by Jos. Lesley, jr.*

The dried soil is like the preceding, very slightly darker colored and more brownish. The clods are a litttle more firm. The coarse sieve separated from it 11.2 per cent. of somewhat rounded, irregular ferro-silicious fragments or concretions. With the bolting-cloth its silicious residue gave similar results with the preceding.

No. 2244—"*Subsoil of the next preceding,*" *&c., &c.*

The dried subsoil is of a warm, brownish, dark-grey color. The clods are quite firm and more reddish in their interior than the powdered soil. The coarse sieve separated from it 10.3 per cent. of irregular, somewhat rounded, ferro-silicious fragments. From its silicious residue, after digestion in acids, the bolting-cloth removed quite a large proportion of small, rounded, friable particles of partly-decomposed concretions, and a few small, rounded grains of white quartz.

No. 2245—"*Virgin soil from the farm of John H. Phillips, Newberry Post-office, eleven miles southwest from Monticello, on the road to Albany, one mile west from Otter creek. Timber: white and black oak, hickory, dogwood. Geological position: Sub-carboniferous limestone. Soil: red ferruginous, on the great undulating plateau of Wayne and Clinton counties.*" *Collected by Joseph Lesley, jr., July,* 1859.

The dried soil is of a grey-brown or light snuff color; friable. The coarse sieve separated from it only 1.5 per cent. of small, rounded, ferruginous, silicious particles. Its silicious residue all passed through the bolting-cloth except very small proportions of small, rounded grains of partly-decomposed concretions and white quartz, with a few silicified portions of very small encrinital stems.

No. 2246—"*Surface soil from a field on the same level as the next preceding, cleared about sixty years ago, which was uninterruptedly in corn for the first twelve or twenty years. Of late years more attention has been paid to alternation of crops; but eight out of ten years of the sixty it has been in corn. Now* (1859) *in wheat stubble.*" *Collected by Jos. Lesley, jr.*

The dried soil is friable, and is of a handsome, light, reddish grey-brown color. The coarse sieve removed from it only 1.6 per cent. of small, rounded, ferruginous, silicious particles. Its silicious residue gave the same result with the bolting-cloth as the preceding.

No. 2247—"*Subsoil of the next preceding soil,*" *&c., &c.*

The dried subsoil resembles the soil next preceding, the color being only a light shade darker, being reddish grey-brown. The coarse sieve removed from it 3.2 per cent. of small, rounded, ferruginous, silicious particles and small quartz pebbles. With the bolting-cloth its silicious residue gave similar results with the two preceding soils.

No. 2248—"*Virgin soil from the farm of Hiram T. Hall, on the road from Albany to Monticello, six and three quarter miles southwest of the latter, and half way between Otter and Beaver creeks. Geological position: Sub-carboniferous limestone; red ferruginous horizon. Remarks: This specimen is taken from the so-called 'flat lands' of this county, which hereabout extend over a wide surface, and are estuary-like, being bays between long, low, wide noses which give the country a rolling character. Corn and other grains will not grow on it, although timothy and herd-grass are grown with great success. Timber: White and pin oaks, hickory and sugar maple.*" *Collected by Jos. Lesley, jr.*

The dried soil is friable and of a light ash-grey color. The coarse sieve separated from it only a very small proportion of shot iron ore. Its silicious residue all passed through the bolting-cloth, except very small proportions of small, friable, rounded particles of partly-decomposed concretions and of white quartz.

No. 2249—"*Subsoil of the next preceding*," *&c.*, *&c.*

The dried subsoil is much lighter colored than the soil next preceding, being of quite a light, yellowish-grey tint. It has some friable clods. The coarse sieve removed from it only a very small proportion of shot iron ore and small, silicious concretions. The bolting-cloth separated from its silicious residue a considerable proportion of small, rounded particles of partly-decomposed concretions and a few of white and reddish quartz.

No. 2250—"*Virgin soil from the red ferruginous soil horizon, or the Sub-carboniferous limestone formation. From the farm of Hiram T. Hall. This soil is a fair average of the farming lands of this portion of Wayne county.*" *Collected by Joseph Lesley, jr.*

The dried soil is friable and of an umber color. The coarse sieve separated from it 5.8 per cent. of angular, cherty fragments. The bolting-cloth removed from its silicious residue only very small proportions of partly-decomposed concretions and quartz grains.

No. 2251—"*Surface soil from a field adjoining the location of the next preceding, which has been in cultivation every year for sixty years, the first twenty years in corn; now* (1859) *in wheat stubble; last year in corn, and the year before in wheat.*" *Collected by Joseph Lesley, jr.*

The dried soil is friable and of a handsome, reddish, light grey-brown color. The coarse sieve removed from it 1.9 per cent. of angular, cherty fragments, and some little shot iron ore. The bolting-cloth separated from its silicious residue a considerable proportion of small, rounded, friable particles of partly-decomposed concretions and a few of small, rounded, white quartz grains.

No. 2252—"*Subsoil of the next preceding*," *&c.*, *&c.*

The dried subsoil is somewhat cloddy. It is of a handsome light-ferruginous or brick color. The coarse sieve separated from it but a very small proportion of small, cherty particles. The bolting-cloth removed from its silicious residue quite a large proportion of small, rounded grains of partly-decomposed concretions and only a few small, rounded grains of quartz.

No. 2253—"*Virgin soil from the ridge between Big Sinking creek and Elk Spring valley, on the property of Edward Morrow, near the water-shed at the road crossing, three quarters of a mile south of Alexander's coal bank, and five miles east from Monticello. Geological position: Coal-bearing sandstones and shales, seventy feet below the main coal.*" *Collected by Joseph Lesley, jr.*

The dried soil is light and friable and of a very light buff-grey color. The coarse sieve separated from it 33.4 per cent. of pretty large, angular fragments of ferruginous sandstone, mixed with some smaller, rounded ones. From its silicious residue the bolting-cloth removed very few small, rounded particles of partly-decomposed concretions and quartz.

No. 2254—"*Virgin soil from a ridge dividing Cedar Sinking creek from Dry valley, near Double-headed Gap, in the north-east portion of the county. Geological position: Coal-bearing sandstones and shales, seventy feet above the top of the Sub-carboniferous limestone.*" *Collected by Joseph Lesley, jr.*

Dried soil friable; of a purplish-grey color: ash-grey. The coarse sieve separated from it 21.2 per cent. of angular fragments of ferruginous sandstone. The bolting-cloth removed from its silicious residue only a small proportion of particles of partly-decomposed concretions and no quartz grains.

COMPOSITION OF THESE WAYNE COUNTY SOILS, DRIED AT 212° F.

	No. 2239	No. 2240	No. 2241	No. 2242	No. 2243	No. 2244	No 2245	No. 2246	No. 2247	No 2248	No 2249	No. 2250	No 2251	No. 2252	No. 2253	No 2254
Organic and volatile matters	5.865	4.985	2.675	4.435	4.710	3.350	4.696	5.310	3.015	4.710	2.300	7.640	3.275	2.925	1.850	5 920
Alumina and iron and manganese oxides	8.089	3 944	4.201	6.347	5.817	8.814	9.151	8.922	8.681	5.140	6.031	8.415	8.215	8.279	2 836	5.703
Lime carbonate	.270	.360	.195	.405	.345	.345	.130	.145	.195	.205	.120	.460	.195	.070	.195	.345
Magnesia	.124	.187	.102	.187	.142	.133	.112	.147	.106	.154	.122	.088	.151	.151	.073	.286
Phosphoric acid	.096	.076	.076	.061	.093	.061	.099	.118	.109	.115	.084	.125	.125	.061	.029	.087
Potash, extracted by acids	.217	.166	.282	.206	.201	.220	.260	.266	.192	.212	.170	.184	.126	.259	.021	.249
Soda, extracted by acids	.061	....	....	....	....	.014	.059	.011	....	....	.035	.020	....	.072	.050	.069
Water, expelled at 380° F.	1 850	1.200	1.025	1.265	1.265	1.050	2.440	1.565	1.300	2 090	735	3.650	1.240	.615	.500	1.715
Sand and insoluble silicates	83.290	88.990	91.865	87.490	87.130	85.740	83.115	84.265	86.465	87.015	90.615	79.315	86 415	86.990	94.590	85.690
Total	99.862	99.908	100 421	100.396	99.703	99.727	100.061	100 749	100.063	99.641	100.212	99.897	99.742	99.422	100.144	100.064
Hygroscopic moisture	2.025	1.435	0.900	1.560	1.500	1.650	2.335	1.510	1.525	1.560	1.185	3.150	1.475	1.625	0.440	1.565
Potash in the insoluble silicates	.931	651	.566	.614	.762	.859	.784	.729	.772	.570	.531	1.012	.799	.878	.711	.984
Soda in the insoluble silicates	.279	.196	.168	.159	.199	.183	.284	.289	.199	.127	.227	.262	.199	.161	.152	.274
Percentage of gravel	7.500	4.400	16.500	6.600	11.200	10.300	1.500	1.600	3.200	sm p'n.	sm. p'n	5.800	1.900	sm. p'n.	33.400	21.200
Character of the soil	Virgin soil.	Cultiv'd field.	Subsoil.	Virgin soil	Old field soil.	Subsoil	Virgin soil.	Old field soil	Subsoil	Virgin soil.	Subsoil	Virgin soil.	Old field	Subsoil.	Virgin soil.	Virgin soil.

All of these soils, which are based on the Sub-carboniferous limestone formation, appear, from their chemical composition and physical condition, to be very good and fertile, requiring only good management to make them productive. This is especially the case with No. 2250, said by Mr. Lesley to be a fair average of the farming lands of the red ferruginous horizon, in Wayne county, which may be classed among our rich soils. No. 2248 is said not to produce corn or other grains, but to be favorable to the growth of timothy and other grasses. As no reason for this default appears in its analysis, it is probably due to imperfect local drainage.

In all these soils the subsoils seem to be less rich than the surface soils ; so that, for the present at least, no other benefit would result from deep plowing except that of loosening the substratum for more perfect drainage, or the extension of the roots of growing crops.

Soils Nos. 2239, 2240, and 2241, especially the subsoil, show the presence of the débris of the sandstones and shales lying above them; and soil No. 2253, lying on the water-shed of a ridge on the coal-bearing sandstones and shales, which is the poorest of all these soils, shows in a marked manner the deteriorating effects of the wash of the atmospheric waters through it, especially in its large proportions of gravel, sand and insoluble silicates, and its small quantities of organic matters, potash, soda, phosphoric acid, alumina, &c. Soil No. 2254, from a similar geological position and also on a ridge, shows much less of the effects of this surface washing, probably because it may be more favorably located in relation to the drainage, and may be considered a soil of good average fertility, under good management, notwithstanding its 21.2 per cent. of small, rocky fragments of coarse gravel, which diminishes its value about one fifth.

WEBSTER COUNTY.

SOILS.

No. 2255—"*Virgin soil from the farm of Col. Scott, Sebree City, on the L. and S. E. Railroad. Timber: white and red oaks, dogwood, whitewood, black walnut,*" *&c. Collected by C. W. Beckham.*

The dried soil is of a brownish umber-grey or chocolate-grey color. The clods are friable. It all passed through the coarse sieve except a little vegetable débris. Its silicious residue (*i. e.*, sand and insoluble silicates) all passed through the bolting-cloth except a very few small silicious grains.

No. 2256—"*Surface soil from a field seventy-five years in cultivation in corn and tobacco. Same locality as that of the preceding soil, but on a hill fifteen feet above the flats.*" *Collected by C. W. Beckham.*

The dried soil is generally of a dull brownish yellow-ochre color, mottled with reddish in the clods, which are quite firm. It contains fragments of charcoal. It all passed through the coarse sieve except a few small fragments of friable sandstone. The bolting-cloth removed from its silicious residue but a small proportion of small, rounded grains of white quartz and of partly-decomposed concretions.

No. 2257—"*Subsoil of the next preceding,*" *&c., &c.*

The dried subsoil is of a brighter brownish yellow-ochre color than the preceding. Its clods are quite firm. It all passed through the coarse sieve. Its silicious residue gave the same results with the bolting-cloth as that of the preceding.

No. 2258—"*Surface soil from a field more than fifty years in cultivation. Tobacco and corn the principal crops. Farm of Mr. Kaufman, Slaughterville Station, L. and S. E. Railroad.*" *Collected by C. W. Beckham.*

The dried soil is quite friable and of a brownish yellowish dark-grey color. It all passed through the coarse sieve. Its

silicious residue gave the same results with the bolting-cloth as the preceding.

No. 2259—"*Subsoil of the next preceding; used for making bricks,*" *&c.*

The dried subsoil is in quite firm clods, of a browish yellow-ochre color. It all passed through the coarse sieve.

No. 2260—"*Surface soil from a field ten years in cultivation; principally in corn and tobacco. Farm of A. G. Brooks, Elmwood Station, L. and S. E. Railroad.*" *Collected by C. W. Beckham.*

The dried soil is of a brownish-drab or dirty-buff color. Its clods are friable. It all passed through the coarse sieve, leaving on it only some vegetable débris. With the bolting-cloth its silicious residue gave the same results as the preceding soils.

No. 2261—"*Subsoil of the next preceding,*" *&c., &c.*

The dried subsoil is of a brownish-buff color, brighter than that of the preceding. Its clods are quite firm, and mottled with lighter-buff and ochreous tints. It all passed through the coarse sieve except vegetable débris and a few small ferruginous concretions. Its silicious residue gave the same results with the bolting-cloth sieve as the preceding soils of this collection.

COMPOSITION OF THESE WEBSTER COUNTY SOILS, DRIED AT 212° F.

	No. 2255	No. 2256	No. 2257	No. 2258	No. 2259	No. 2260	No. 2261
Organic and volatile matters	3.975	5.035	3.365	2.610	2.440	3.450	2.210
Alumina & iron & manganese oxides	4.225	8.480	11.383	4.665	7.661	3.986	5.639
Lime carbonate	.330	1.895	.220	.145	.120	.270	.145
Magnesia	.277	.436	.450	.160	.241	.184	not est.
Phosphoric acid	.140	.285	.157	.125	.054	.094	.061
Potash extracted by acids	.064	.313	.392	.124	.071	.126	.108
Soda extracted by acids	.323	.030	.040	.012	.016	.057	.439
Water expelled at 380° F.	.950	.900	.800	.565	.585	1.250	.775
Sand and insoluble silicates	89.855	82.940	83.205	91.445	88.755	90.490	90.815
Total	100.139	100.314	100.012	99.851	99.943	99.907	100.192
Hygroscopic moisture	1.680	2.850	3.325	1.200	1.975	1.575	1.365
Potash in the insoluble silicates	1.697	1.730	1.956	1.544	1.779	1.570	1.750
Soda in the insoluble silicates	.672	.482	.563	.712	.690	.746	.366
Character of the soil	Virgin soil	Old field soil.	Subsoil.	Old field soil.	Subsoil.	Cultivated field.	Subsoil.

The soil of the old field, seventy-five years in cultivation in tobacco and corn, with its subsoil, Nos. 2256 and 2257, must have been naturally much richer than the virgin soil, No. 2255, of its neighborhood, if the labels accompanying the samples are correct; for, notwithstanding its prolonged use in the production of exhausting crops, it contains much larger proportions of the essential elements of fertility than that, and may yet be classed amongst the rich soils. Most of these described above are at least of average fertility, the only apparent deficiency being of available potash in Nos. 2255 and 2259, and of phosphoric acid in Nos. 2260 and 2261, and in subsoils 2259 and 2261—ingredients which can readily be supplied in appropriate fertilizers. These soils are all in a favorable physical condition, being friable and in a state of fine division, and containing no gravel.

TABLE I. SOILS, SUBSOILS, AND UNDER-CLAYS, DRIED AT 212° F.

Number.	County.	Organic and volatile matters.	Alumina and iron oxide, &c.	Lime carbonate	Magnesia.	Phosphoric acid	Potash.	Soda.	Water expelled at 380° F.	Sand and insoluble silicates.	Water expelled at 212° F.	Potash in the insoluble silicates.	Soda in the insoluble silicates.	Gravel.	Remarks.
2096	Ballard. . .	4.065	5.904	1.095	0.394	0.246	0.289	0.242	0.935	87.120	2.000	1.619	0.680	. . . .	Top soil Bar's, 4 yrs. in cult.; W. H. Reeves.
2097	Ballard. . .	2.790	7.597	.295	.308	.093	.449	.148	.760	87.395	2.300	1.482	.674	. . . .	Subsoil of the same.
2098	Ballard. . .	2.185	8.557	.195	.544	.093	.131	.653	.450	87.110	2.735	1.085	.536	. . . .	S'bs'l or un'r-clay; uplands around Blandville.
2099	Ballard. . .	1.565	7.835	.645	.601	.140	.175	.309	.435	87.495	2.300	2.138	1.208	. . . .	Sub. or un'r clay, uplands sev'l ft. below surface.
2100	Ballard. . .	3.210	6.150	.155	.268	.115	.203	.364	1.065	88.890	1.865	1.659	1.165	. . . .	Virgin soil; bottom land, Mayfield creek.
2101	Ballard. . .	2.565	3.864	.385	.163	.061	.319	.362	.635	92.010	1.075	1.358	.616	. . . .	Old field soil; bottom land, Mayfield creek.
2102	Ballard. . .	2.125	5.088	.245	.184	.077	.276	.129	.675	91.570	1.125	1.401	.911	. . . .	Subsoil of next preceding.
2109	Clinton. . .	6.615	5.084	.405	.232	.166	.212	not est.	1.400	84.990	1.585	.983	.217	22.40	Virgin soil; sub-car. limestone; Lewis Huff's.
2110	Clinton. . .	9.275	6.687	.620	.232	.173	.274	not est.	1.810	81.165	1.990	.998	.101	27.00	Cultiv'd soil; sub-car. limestone; Lewis Huff's.
2111	Clinton. . .	6.910	6.951	.480	.223	.259	.222	not est.	1.665	83.365	1.750	.972	.158	14.20	Subsoil of next preceding.
2112	Clinton. . .	3.000	2.932	.080	.106	.093	.155	not est.	1.550	92.240	.900	.327	.169	29.50	Virgin soil; sub-car. limestone; Jno. Wade's.
2113	Clinton. . .	4.320	6.129	.295	.124	.071	.170	not est.	1.940	86.790	1.800	.726	.263	4.40	Old field soil; sub-car. limestone; J. Wade's.
2114	Clinton. . .	4.695	6.247	.195	.108	.093	.188	not est.	1.500	86.790	1.515	.621	.169	8.20	Subsoil of next preceding.
2115	Crittenden .	2.225	3.629	.160	.304	.086	.090	not est.	.875	92.705	.890	1.876	.896	. . . .	Virgin soil; ridge; sandst'e; S. C. B. McMican.
2116	Crittenden .	2.950	8.718	.145	.350	.092	.309	.118	.925	86.665	.925	2.023	.750	. . . .	Subsoil of next preceding.
2117	Crittenden .	3.260	4.868	.270	.214	.067	.171	not est	1.225	89.440	1.565	1.707	.694	. . . .	Cultivated field, same locality.
2118	Crittenden .	2.885	8.173	.170	.703	.102	.122	not est.	.950	86.490	2.000	1.755	.588	. . . .	Subsoil of same field.
2123	Fulton . . .	9.305	10.437	1.385	.461	.198	.142	not est	3.110	74.840	4.100	1.889	.607	. . . .	Top soil; Mississippi bottom land.
2124	Fulton . . .	4.725	5.127	1.045	.234	.198	.321	.419	1.150	87.145	2.350	1.814	.858	. . . .	Cultivated soil; Mississippi bottom land.
2125	Fulton . . .	3.075	5.335	.360	.175	.055	.179	not est.	1.025	89.945	1.685	1.767	.828	. . . .	Virgin soil; Dr. G. W. Pascal's.
2126	Fulton . . .	2.300	4.974	.190	.162	.156	.290	.124	.775	91.745	1.400	1.664	.749	. . . .	Old field soil; Dr. G. W. Pascal's.
2127	Fulton . . .	2.535	8.690	.195	.331	.125	.141	.098	.900	86.895	2.585	1.892	.715	. . . .	Subsoil of the next preceding.
2128	Fulton .	3.090	3.825	.395	.214	.125	.066	not est.	1.050	91.125	1.335	1.784	1.208	. . . .	Virgin soil; Capt. Henry Tyler's farm.
2129	Fulton . . .	2.285	7.700	.145	.268	.115	.186	.142	.840	87.795	2.610	1.675	.893	. . . .	Subsoil of next preceding soil; same farm.
2130	Fulton . . .	8.375	6.860	1.395	.598	.125	.332	.073	2.650	79.340	3.585	1.865	1.030	. . . .	Old field soil; Mississippi upland; same farm.
2131	Fulton . . .	4.140	10.560	.795	.169	.115	.208	.317	1.501	82.395	3.975	1.873	.841	. . . .	Subsoil of next preceding; same farm.
2132	Fulton . . .	2.860	3.560	.345	.142	.125	.074	.182	.975	91.740	1.000	1.969	.892	. . . .	Virgin soil; upland; same farm.
2133	Fulton . . .	2.165	6.550	.110	.232	.140	.275	.050	.650	89.670	1.725	1.935	.991	. . . .	Subsoil of next preceding.
2150	Henderson .	4.525	5.004	.570	.317	.131	.196	.112	1.225	87.990	1.815	1.654	.775	. . . .	Virgin soil; woodland pasture; W. Thompson's.
2151	Henderson .	3.150	3.968	.385	.241	.102	.238	.143	.865	91.315	1.200	1.619	.815	. . . .	Cultivated field; W. Thompson's.
2152	Henderson .	2.780	5.879	.520	.304	.061	.142	not est.	.735	89.215	1.900	2.036	.570	. . .	Subsoil of next preceding; W. Thompson's.
2153	Henderson .	2.125	5.979	.195	.245	.061	.236	not est.	.420	90.725	1.350	1.672	.763	. . . .	Old field soil; J. D. Robsard's.
2154	Henderson .	2.900	10.047	.130	.304	.093	1.097	not est.	.550	85.365	2.575	1.755	.608	. . . .	Subsoil of the same; J. D. Robsard's.
2155	Henderson .	3.465	3.113	.120	.166	.077	.363	.165	.600	92.290	1.175	1.121	.742	. .	Virgin soil; woods pasture; Mr. Klute.
2156	Henderson .	3.025	4.048	.195	.196	.067	.550	not est.	.600	91.625	1.325	1.127	.714	. . . .	Old field soil; Mr. Klute.
2157	Henderson .	3.290	9.589	.950	.342	.061	.429	.185	.580	85.040	1.850	1.128	.819	. . . .	Subsoil of next preceding; Mr. Klute.
2158	Henderson .	3.835	3.364	.220	.175	.061	.371	not est.	.715	91.665	1.125	1.274	.846	. . . .	Virgin soil; woods pasture; S. H. Busbey's.
2159	Henderson .	2.785	4.129	.220	.309	.061	.382	.123	.566	91.840	1.025	1.457	.704	. . . .	Old field soil; S. H. Busbey's.
2160	Henderson .	3.350	9.644	.195	.195	.121	.357	.109	.675	85.890	2.100	1.573	.611	. . . .	Subsoil of the same; S. H. Busbey's.
2161	Hickman . .	4.140	3.694	.495	.232	.156	.182	.564	1.010	90.095	1.735	1.899	.573	. . . .	Upland soil, two years in cultivation.
2206	Madison . .	7.240	10.353	2.485	.989	.387	.545	.162	1.122	76.715	3.275	1.949	.206	sm. p'n	Top soil, in cult. 26 yrs; on Cumberland shales.
2207	Madison . .	7.150	10.905	1.870	.809	.300	.638	not est.	1.450	77.395	3.775	2.079	.281	sm. p'n	Subsoil of same field.
2208	Madison . .	2.950	11.032	.220	.160	.173	.359	not est.	.800	84.174	2.575	1.800	.407	sm. p'n	Bottom clay, under the preceding.

TABLE I. SOILS, SUBSOILS, AND UNDER-CLAYS, DRIED AT 212° F.—Continued.

Number.	County.	Organic and volatile matters.	Alumina and iron oxide, &c.	Lime carbonate.	Magnesia.	Phosphoric acid.	Potash.	Soda.	Water expelled at 380° F.	Sand and insoluble silicates.	Water expelled at 212° F.	Potash in the insoluble silicates.	Soda in the insoluble silicates	Gravel.	REMARKS.
2212	McCracken	1.840	5.883	0.070	0.200	0.082	0.186	0.314	0.485	90.920	1.500	1.773	0.855	sm. p'n	Subsoil; land of Dr S. B. Caldwell.
2213	Nelson . .	3.360	7.977	.270	.166	.108	.116	.225	1.215	86.650	1.485	1.669	.274	1.400	Cul'd field, near Rohan's Knob; Mr. Ballard's
2214	Nelson . .	2.990	10.349	.245	.187	.061	.164	.045	.900	85.075	2.525	1.835	.400	.500	Subsoil of the same.
2215	Nelson . .	3.300	14.368	.880	.809	.102	.361	.657	2.415	76.840	1.129	2.742	.225	1.000	Under-clay of the same.
2217	Pulaski. . .	3.890	5.661	.125	.088	.089	.345	.027	.925	88.690	.915	.642	.205	31.600	Virgin soil on ridge; farm of Mr. Taylor.
2218	Pulaski. . .	4.200	5.640	.095	.070	.045	.222	. . . .	1.000	88.765	1.315	.927	.287	9.200	Virgin soil on ridge; coal-measures.
2219	Pulaski. . .	6.375	6.726	.345	.124	.059	.277	.139	1.425	84.350	1.900	.852	.139	19.200	Cultivated soil; same locality.
2220	Pulaski. . .	3.260	7.894	.095	.124	.076	.066	.256	.790	87.640	1.235	.878	.220	34.700	Subsoil of next preceding.
2221	Pulaski. . .	2.135	4.090	.170	.052	.045	.147	.071	.525	92.765	2.135	.778	.260	13.800	Virgin soil, on sub-carboniferous limestone.
2222	Pulaski. . .	2.550	5.109	.245	.097	.076	.151	.060	.650	91.240	.900	.967	.349	15.000	Old field, in same locality.
2223	Pulaski. . .	2.140	6.240	.170	.128	.045	.217	.083	.560	90.540	.965	1.047	.340	3.100	Subsoil of the next preceding.
2224	Pulaski. . .	2.225	7.767	.195	.213	.083	.351	. . . .	.525	88.790	.775	1.737	.289	4.500	Under-clay of next preceding.
2225	Pulaski. . .	4.590	4.938	.210	.115	.087	.145	.089	1.535	88.340	1.750	.953	.223	8.000	Virgin soil; sub-car. limestone; "Barrens."
2226	Pulaski. . .	5.615	7.072	.295	.146	.118	.100	.084	1.985	84.500	1.525	.863	.199	1.500	Old field soil; same locality.
2227	Pulaski. . .	3.790	7.847	.130	.122	.093	.213	n. e.	1.400	86.675	1.200	.762	.230	sm. p'n	Subsoil of the next preceding.
2228	Pulaski. . .	4.300	8.282	.310	.115	.148	.149	n. e.	1.700	84.990	1.225	.826	.167	sm. p'n	Old field soil; same locality.
2229	Pulaski. . .	3.700	8.923	.220	.115	.077	.149	n. e.	1.550	85.490	1.340	.795	.160	sm p'n	Subsoil of next preceding.
2230	Rockcastle .	6.890	7.126	.345	.223	.109	.366	.093	1.925	82.690	2.085	.925	.128	14.500	Virgin soil; coal-bearing sandstones and shales
2231	Rockcastle .	4.150	3.877	.085	.120	.083	.100	n. e.	.750	90.665	.900	.671	.201	21.400	Virgin soil; ridge; millstone grit.
2232	Rockcastle	4.950	7.342	.435	.232	.093	.231	.008	1.300	85.065	1.775	.918	.312	12.500	Virgin soil; slopes of sub-car. limestone.
2233	Rockcastle .	6.065	8.565	.640	.153	.146	.339	n. e.	1.650	82.040	2.225	.815	.248	17.400	Old field soil; same locality.
2234	Rockcastle .	4.265	8.490	.625	.175	.220	.453	.125	1.375	83.890	1.915	.857	.260	12.000	Subsoil of the next preceding.
2235	Rockcastle .	4.500	7.097	.495	.130	.173	.208	.002	1.300	85.980	1.510	.756	.250	29.000	Old field soil; same locality.
2236	Rockcastle .	3.360	7.025	.395	.187	.125	.254	.031	.965	87.690	1.250	.690	.234	28.600	Subsoil of next preceding.
2239	Wayne . .	5.865	8.089	.270	.124	.096	.217	.001	1.850	83.290	2.025	.931	.279	7.500	Virgin soil; sub-car. limestone; upper part.
2240	Wayne . .	4.985	3.944	.360	.187	.076	.166	. . . .	1.200	88.090	1.435	.651	.196	4.400	Cultivated field soil; same locality.
2241	Wayne . .	2.675	4.201	.195	.102	.076	.282	. . . .	1.025	91.865	.900	.566	.168	16.500	Subsoil of next preceding.
2242	Wayne . .	4.435	6.347	.405	.187	.061	.206	. . . .	1.265	87.490	1.560	.614	.159	6.600	Virgin soil; sub-car. limestone; middle part.
2243	Wayne . .	4.710	5.817	.345	.142	.093	.201	. . . .	1.265	87.130	1.500	.762	.199	11.200	Old field soil; same locality.
2244	Wayne . .	3.350	8.814	.345	.133	.061	.220	.014	1.050	85.740	1.650	.859	.183	10.300	Subsoil of next preceding
2245	Wayne . .	4.695	9.151	.130	.112	.099	.260	.059	2.440	83.115	2.335	.784	.284	1.500	Virgin soil: sub-car. limestone; ferrug. horizon
2246	Wayne . .	5.310	8.022	.145	.147	.118	.266	.011	1.565	84.265	1.510	.729	.289	1.600	Old field soil: same locality.
2247	Wayne . .	3.015	8.681	.195	.106	.109	.192	. . . .	1.300	86.465	1.525	.772	.199	3.200	Subsoil of next preceding.
2248	Wayne . .	4.710	5.140	.205	.154	.115	.212	. . . .	2.090	87.015	1.560	.570	.127	sm. p'n	Virgin soil; sub-car. limestone red fer. horizon
2249	Wayne . .	2.300	6.031	.120	.122	.084	.170	.035	.735	90.615	1.185	.531	.227	sm p'n	Subsoil of next preceding.
2250	Wayne . .	7.640	8.415	.460	.083	.125	.184	.020	3.650	79.315	3.150	1.012	.262	5.800	Virgin soil; same formation.
2251	Wayne . .	3.275	8.215	.195	.151	.125	.126	. . . .	1.240	86.415	1.475	.799	.109	1.900	Old field soil; same formation.
2252	Wayne . .	2.025	8.279	.070	.151	.061	.259	.072	.615	86.990	1.625	.878	.161	sm. p'n	Subsoil of next preceding.
2253	Wayne . .	1.850	2.836	.195	.073	.029	.021	.050	.500	94.590	.440	.711	.152	33.400	Virgin soil; ridge; coal-bearing sandst. & shales
2254	Wayne . .	5.920	5.703	.345	.286	.087	.249	.069	1.715	85.690	1.565	.984	.274	21.200	Virgin soil; ridge; coal-bearing sandst. & shales.
2255	Webster . .	3.975	4.275	.330	.277	.140	.004	.323	.950	89.855	1.680	1.697	.672	. . . .	Virgin soil: farm of Col. Scott.
2256	Webster . .	5.035	8.480	1.895	.436	.285	.313	.030	.900	82.940	2.850	1.730	.482	. . . .	Old field soil; same locality.
2257	Webster . .	3.365	11.383	.220	.450	.157	.392	.040	.800	83.205	3.325	1.956	.563	. . . .	Subsoil of next preceding.
2258	Webster . .	2.610	4.665	.145	.160	.125	.124	.012	.565	91.445	1.200	1.544	.712	. . . .	Old field soil; farm of Mr. Kaufman.
2259	Webster . .	2.440	7.661	.120	.240	.054	.071	.016	.585	88.755	1.975	1.779	.690	. . . .	Subsoil of next preceding.
2260	Webster . .	3.450	3.986	.270	.184	.094	.126	.057	1.250	90.490	1.575	1.570	.746	. . . .	Field 10 yrs in cultv'n; farm of A. G. Brooks.
2261	Webster . .	2.210	5.639	.145	n. e.	.061	.108	.439	.775	90.815	1.365	1.750	.366	. . . .	Subsoil of next preceding.

TABLE II. CLAYS, DRIED AT 212° F.

Number.	County, &c.	Silica.	Alumina.	Iron oxide.	Lime.	Magnesia.	Potash.	Soda.	Water and loss.	Fine sand.	REMARKS.
2104	Ballard. . .	74.460	18.070	1.633	0.314	0.245	0.940	0.021	4.317	48.00	Near Moore's mill, near Blandville; four feet thick.
H	Germany .	70.860	20.900	1.560	.347	.220	.578	.112	6.800	4.00	German glass-pot clay.
I	Germany .	73.660	19.460	1.560	.168	.209	.520	.046	6.200	3.50	German glass-pot clay.
2105	Ballard. . .	67.501	23.051	2.109	.257	.065	.412	.020	6.585	n. e.	South Ballard county; T. D. Campbell's.
2134	Fulton . . .	64.800	21.070	5.270	1.400	.050	.646	.202	6.562	"	Hickman bluffs; indurated clay.
2135	Fulton . . .	76.860	14.600	3.020	.425	.308	.736	.257	3.794	"	Hickman bluffs; ninety-five feet above low water.
2136	Fulton . . .	83.380	9.800	2.120	.963	.187	.617	.118	2.815	"	Hickman bluffs; first beneath gravel.
2137	Fulton . . .	71.340	17.190	2.770	1.612	.209	.925	.232	5.722	"	Hickman bluffs; first beneath gravel.
2138	Fulton . . .	83.500	9.940	2.500	.358	.173	.539	.109	2.881	"	Hickman bluffs; ten feet below the gravel
2139	Fulton . . .	71.080	19.050	2.810	.627	.403	.578	.225	5.227	"	Hickman bluffs; above the next preceding.
2140	Fulton . . .	74.100	16.460	2.700	.358	.187	.559	.135	5.501	"	Hickman bluffs; below the preceding
2141	Fulton . . .	77.960	13.970	2.390	.134	.163	.797	.124	4.462	"	Hickman bluffs; above the railroad track.
2142	Fulton . . .	68.860	12.980	2.240	9.587	1.182	1.773	1.278	2.100	"	Loess or "Bluff:" Quaternary.
2143	Graves . . .	75.550	16.751	1.198	a trace	.144	1.094	.216	5.047	63.00	On Panther creek; W. P. Arnett's land.
2161	Hickman. .	76.360	14.951	2.109	.325	.173	1.171	.125	4.786	69.00	From Chalk bluff, below Columbus.
2162	Hickman. .	84.918	10.560	1.102	.572	.108	.651	n. e.	2.089	68.50	From bluffs, upper part of Columbus.
2168	Madison . .	62.560	24.780	1.800	a trace	.317	3.276	.294	6.973	n. e.	Near Bybertown; M. Barlow's.
2169	Madison . .	64.566	20.160	4.200	.213	.641	5.054	n. e	5.166	"	Near Waco; below Corniferous limestone.
2170	Madison . .	62.580	22.940	3.760	.560	.425	5.280	.308	4.147	"	Indurated clay, near Elliston; Corniferous limestone.
2211	McCracken.	64.480	24.691	1.869	.448	.137	1.457	.083	6.835	"	Near Paducah.

TABLE III. MARLY CLAYS AND SHALES, DRIED AT 212° F.

Number.	County.	Silica.	Alumina.	Iron Peroxide.	Lime.	Magnesia.	Phosphoric acid.	Potash.	Soda.	Water, &c., and loss	REMARKS.
2120	Fayette	53.780	23.260	1.300	4.866	0.568	0.191	7.612	0.550	7.873	In Lower Silurian limestone strata.
2165	Jefferson	47.960	21.340	6.600	5.825	3.524	n. e.	5.265	.250	9.238	In limestone layers of Cincinnati Group.
2166	Jefferson	58.840	19.940	6.000	3.226	.857	"	4.490	.685	5.962	In limestone layers of Keokuk Group.
2167	Jefferson	61.900	18.520	6.220	.123	1.259	"	4.867	.612	6.499	In limestone layers of Keokuk Group.
2186	Madison	42.300	20.840	4.120	13.320	.461	"	2.387	.351	16.221	In Niagara Group, on Drowny creek.
2187	Madison	48 780	17.320	3.240	*19.285	.496	"	4.768	.240	5.871	Beneath Corniferous limestone; bed six feet or more.
2216	Nelson	61.100	18.200	6.000	4.904	1.542	"	4.101	821	3.332	At the base of the Corniferous; many feet thick.

* Lime sulphate; gypsum or plaster of Paris.

TABLE IV. COALS, &c., AIR DRIED.

Number.	County.	Specific gravity	Hygroscopic moisture.	Volatile combustible matters	Coke.	Total volatile matters.	Fixed carbon in the coke.	Ash.	Character of the coke.	Color of the ash.	Percentage of sulphur.	REMARKS.
2144	Graves	n. e.	4.13	16.22	79.65	20.35	10.25	69.40	Pulverulent . . .	Nearly white . .	n. e.	Bitum. shale; "brown coal;" Panther creek.
2145	Greenup	1.319	5.00	39.00	56.00	44.00	49.88	6.12	Spongy	Lilac-grey	1.986	Splint coal (No. 3): Fulton Coal Co.; stock.
2146	Greenup	1.286	2.00	47.36	50.64	49.36	38.24	12.40	Slightly coherent.	Grey-buff	1.554	Can. c'l (No. 4): Ind'n Run; Ful. C'l Co.; st'k
2147	Greenup	1.331	4.80	36.90	58.30	41.70	51.20	7.10	Dense	Lilac-grey	3.977	Coal (No. 4); Chinn's branch; Ful. C'l Co.; st'k
2148	Greenup	1.324	6.00	33.48	60.52	39.48	56.14	4.38	Dense	Lilac-grey . . .	2.330	Coal (No. 7); Coalton coal; Ful. C'l Co.; stock

TABLE V. IRON ORES, DRIED AT 212° F.

Number.	County.	Iron peroxide	Alumina & phosphoric acid.	Lime carbonate.	Magnesia carbonate.	Water, alkalies, &c., and loss	Bituminous matter, water, and loss.	Silicious residue.	Percentage of iron.	REMARKS.
2149	Harrison	21.200	12.870	1.290	6.621	8.329	. . . .	49.690	14.840	Thomas Hinkston's iron ore.
2201	Madison	28.440	5.240	.190	1.279	8.631	. . . .	56.220	18.890	Bog ore on the black shale formation.
2202	Madison	19.800	9.880	.380	1.844	5.806	. . . .	62.290	13.860	Bog ore on the black shale formation.
2203	Madison	30.870	11.560	.290	.897	6.403	. . . .	49.980	21.570	Bog ore on the black shale formation.
2204	Madison	17.300	14.820	.130	1.041	10.449	. . . .	56.260	12 110	Bog ore on the Corniferous formation.
2205	Madison	19.500	16 360	trace.	trace	. . . .	24.200	39.940	13.650	Black band ore; on top of the coal; Comb's knob.

TABLE VI. LIMESTONES, DRIED AT 212° F.

Number.	County.	Lime carbonate.	Magnesiacarbonate.	Alumina.	Iron oxide.	Phosphoric acid.	Potash.	Soda.	Silicious residue.	Percentage of lime.	Percentage of magnesia.	Silica.	Water, bitumen, &c., and loss.	REMARKS.
2121	Franklin . .	70.360	6.784	5.458	1.342	n. e.	1.118	0.281	. . . .	39.401	3.236	14.020	. . . .	Kentucky river bluffs; Trenton Group
2189	Madison . .	48.530	11.790	10.330			1.696	.347	20.740	27.173	5.614	n. e.	6.567	Top of Cincinnati Group.
2190	Madison . .	37.760	10.050	17.656	3.700	0.204	.458	.090	25.180	21.145	4.785	20.980	4.902	On the top of Cumberland shales.
2191	Madison . .	33.560	6.855	21.560	4.120	.204	.578	.045	29.180	18.794	3.251	22.800	4.302	On the top of Cumberland shales.
2192	Madison . .	45.700	27.475	11.360	3.500	. . . .	.501	.088	9.980	25.592	13.083	n. e.	1.396	On the top of Cumberland shales.
2193	Madison . .	50.860	20.100	9.960	3.900	. . . .	.276	.054	3.980	28.480	9.608	n e.	10.870	Upper Silurian.
2194	Madison . .	50.960	27.972	5.960	*3.556	. . . .	.276	.087	4.120	28.538	13.319	n. e.	6.493	Upper Silurian.
2195	Madison . .	51.200	25.124	12.360	4.460	.140	.287	.049	3.920	28.672	11.899	n. e.	2.460	Upper Silurian.
2196	Madison . .	35.160	4.646	10.706	2.060	.754	2.033	.586	39.780	19.689	2.212	n. e.	4.275	Clinton Group.
2197	Madison . .	43.060	9.994	9.420	2.640	. . . .	.770	.149	22.680	24.113	4.756	n. e.	11.287	From Canda-Galli grit.
2198	Madison . .	41.150	13.908	9.040	1.890	. . . .	n. e.	n. e.	20.990	23.044	6.384	n e.	n. e.	From above Corniferous limestone.
2199	Madison . .	36.580	18.541	4.010	1.540	. . . .	n. e.	n. e.	31.990	20.485	8.781	n. e.	n. e.	Top of Corniferous limestone.
2200	Madison . .	47.580	17.133		10.980	. . . .	n e.	n. e.	18.190	26.645	8.158	n. e.	6.117	Top of Corniferous limestone.
d 521	Jefferson . .	50.430	18.670		2.930	.060a	.320	.130	25.780	28.290	8.890	22.580	.100	Hydraulic; Falls of Ohio.
e 1068	Indiana . .	45.880	22.911	5.760		.220b	.347	.372	21.520	25.746	10.914	(c)	2.721	Hydraulic; Madison, Indiana.

(d). From Vol. II, first series Ky. Geol. Rep., p. 220, for comparison. (e) From Vol. IV, first ser. Ky Geol. Rep., p. 101, for comparison. * Iron sulphide 0.576 in addition.
(a). Sulphuric acid, 1.580. (b). Sulphuric acid, 0.269. (c). Silica soluble in solution of carb. soda=3.000.

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