DEPT OF GEOLOGY
VANDERBILT UNIV

Kentucky Geological Survey

CHARLES J. NORWOOD, Director.

REPORT

ON THE

Progress of the Survey

FOR THE YEARS 1908 AND 1909.

By CHARLES J. NORWOOD.

LEXINGTON, KENTUCKY.

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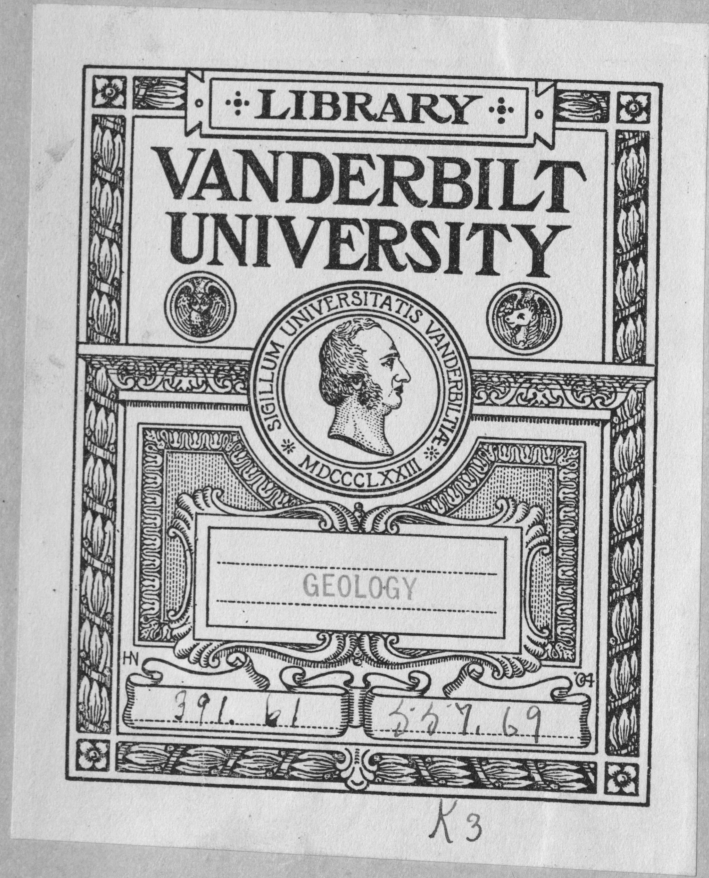

DEPT. OF GEOLOGY
VANDERBILT UNIV.

LETTER OF SUBMITTAL

To His Excellency, AUGUSTUS E. WILLSON,
Governor of Kentucky.

Sir: I have the honor to submit the following report on the progress of the Geological Survey for the calendar years 1908 and 1909, for your consideration and for transmittal to the General Assembly. Very respectfully,

CHARLES J. NORWOOD,
Director, Kentucky Geological Survey.

January 31, 1910.

PERSONNEL OF THE SURVEY

The following persons now hold or have held positions on the Survey during the period covered by this report. They are named in the order of their appointment under each class

Director.—Charles J. Norwood.

Assistants in Geology.—Joseph B. Hoeing (also Cartographer), until April, 1908. Mr. Hoeing found it necessary to withdraw because of ill health. Arthur M. Miller, until July 1909. Aug. F. Foerste, Albert R. Crandall, F. Julius Fohs, James, M. Hodge, (until March, 1909,) William C. Morse (parts of 1908 and 1909), Leonidas C. Glenn, and F. M. Hutchinson.

Chemistry, Technology, and Soils.—Alfred M. Peter, supervising chemist and in charge of soil testing; Harry D. Easton, assistant in clay testing; James H. McHargue, chemist; Sadocia C. Jones, assistant in soils; and Ralph D. Quickel, aid in fuel testing.

Office.—F. Grider McKay, clerk; Nancy D. Bentley, stenographer; Joseph W. Norwood, draftsman.

Temporary Aids.—T. C. Carroll, field aid in 1908. Page B. Blakemore, in chemical laboratory, part of 1908. Robert G. Stevens, aid in collecting statistics (in co-operation with the U. S. Geological Survey) and in Museum. Kessack D. White and W. Bruce Hager, field aids, season of 1909.

Other persons have been employed occasionally, but only for brief periods.

In the co-operative topographic mapping large field parties, under the direction of topographers of the U. S. Geological Survey, were employed. It is not deemed necessary to give the long list of names here.

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REPORT OF PROGRESS

The scope of the operations of the Geological Survey is indicated by the following provisions, set forth in section five of the Act of 1908: "It shall be the duty of the director of the Survey and his assistants to examine and report upon the economic geology of the State especially, as specified in and in accordance with section five of Chapter 19, Acts of the General Assembly of 1904, said investigations to be conducted along such lines as will prove of practical value in ascertaining and exhibiting the fitness for commercial uses of the various substances reported upon, and to include such standard and practical tests as are necessary and usual in determining the commercial values of the various materials under investigation; and in furtherance of such practical work, the director, should he deem it advisable, is authorized to purchase or lease a drilling machine for use in prospecting regions where the existence or continuation of coals, ores or other useful substances beneath the surface may not be readily determined in any other way, or to make such other arrangements for borings as may appear most feasible and economical. The underground and surface waters of the State shall be investigated, and the director is authorized, should he deem it expedient, to co-operate with the State Forestry Commission in the study of the timbers of the State. Especial attention shall be given to the study of the soils of the State, with reference to their conservation and their fitness for various classes of crops, with a view of determining the proper fertilizers for impoverished or otherwise defective lands, and such results as are appropriate shall be embodied in a soil map; and to the end that the soil investigations may be most effectively carried on, the director is authorized to continue the agreement with the director of the State Agricultural Experiment Station, en-

tered into under authority of Chapter 49 of the Acts of the General Assembly of 1906, for co-operation and assistance in the work. An investigation of road materials shall also be carried on, and such tests be made as come within the means of the Survey, with a view to determining the availability of materials in the various counties of the State for road building, and the best methods of preparing them for local application, and the results shall be embodied in a special bulletin; and the director is authorized to enter into an agreement with such bureau of the Federal Government as may be proper for co-operation in this work. As a contribution toward a better knowledge of the requirements for the safe working of the mines of the State, the technological work of the Survey shall include an investigation of the mine gases and coal dusts and of such other matters as are appropriate, to such extent as the means of the Survey may permit."

It is also provided that, "The reports of the Survey shall consist of subject reports, county reports, miscellaneous bulletins, and a general or index report, accompanied by all diagrams, maps and illustrations necessary to render them full and complete."

The section of the Act of 1904 referred to requires the Survey to give "particular attention to such mineral resources as coal, iron, lead, zinc, barite, fluorite, clays, shales, building stones, asphalt rock, road and paving materials, natural fertilizers, petroleum, natural gas, pigment earths, abrasives, marbles, lithographic stones, and other minerals; determining their location and extent, which shall be shown on appropriate diagrams and maps, their relations to transportation routes, actual and possible, and their chemical and physical qualities to such extent as may be necessary in each case."

The first work of the Survey, under the law and because of conditions that had prevailed for twelve years during which nothing was done by the State to determine our own resources, while Surveys were continuously in operation in, so to speak, rival States, had to be general—dealing with the mineral and other natural resources of the State by subjects. This has carried the Survey into a larger number of counties within a limited time than otherwise would have been the case, and

has been of greater advantage to the Commonwealth as a whole than had reports on particular, restricted areas (such as counties) been the first to be undertaken. A large field has been covered by this general examination, which is bearing fruit in the notable development of the State which is now going on along various lines. As recently stated in an article for the press, it seems quite within bounds to say that the re-establishment of the Geological Survey, immediately following the mineral exhibit made at the St. Louis World's Fair, has resulted in bringing more active capital into the State, and has done more to forward development of lands that hitherto had contributed little to the State treasury, within the last six years, than could otherwise have been accomplished in thrice that period.

Printing of Reports.

Unfortunately, the printing of completed reports has not kept pace with their preparation, and this has resulted in embarrassments for the Survey in various ways. Among other things, it has placed a heavy tax on the time of the Director, in necessitating the preparation of abstracts from reports, completed but unavailable for distribution because unprinted, concerning regions about which inquiries have been received; and this has prevented his keeping abreast of the large general correspondence of the office.

The following reports are now in the hands of the printer, and have been for many months: No. 10, Coals of the Licking Valley and of some of the Contiguous Territory;* No. 11, Coals of the Three Forks of the Kentucky River;* No. 13, Coals of the Western Border of the Eastern Coalfield;* No. 14, Coals of the Pineville Gap Region; No. 15, The Cincinnatian Formation and Its Economic Values; No. 16, General Report on the Lead, Zinc, and Spar Districts of Western Kentucky, (embracing Caldwell, Christian, Crittenden, Livingston, Lyon, and Trigg counties); and a revision of a report on

*This report is in type, and has been for some time.

the natural resources of Livingston county, found in manuscript among the archives of the Survey.

The following reports have been ready for the printer for many months, but have been held in the office until the reports which had been turned over to him should be received: (a) On the Resources of Breckenridge and Meade Counties, being a revision (in accordance with later field investigations) of reports prepared some years ago; (b) Mining Thin Coal Seams; (c) Key to the State Geological Map. A report on the Coals of the Western Field, which had been prepared, has been withheld in order that advantage may be had of the mapping which has been carried on in that field during recent years; other and more satisfactory reports, two of which are in preparation and should be ready for printing by next May or June, will be substittued for it.

Eleven reports, ready for the printer or in course of preparation, will be noted under appropriate headings. Abstracts from eight of them are given in this report, in order that present needs may to some extent be satisfied.

The Coal Fields.

Coals of the Tug Fork in Martin and Pike Counties.—One of the most important contributions toward an understanding of the coals in the important region bordering the Tug Fork of the Big Sandy is the report of Prof. A. R. Crandall, based on field work carried on in 1909, of which a summary is given in this report; it will be found quite helpful, not only to engineers engaged in the field included in the Tug drainage, but to all who are interested in other portions of the Big Sandy Valley. Among the important features of the report, especially to investors who are familiar with West Virginia names, are the correlations of the seams, now given for the first time. According to Prof. Crandall, equivalencies are as follows:

No. 1, (*according to the old nomenclature*).—This is the Warfield, of Martin county; the Paintsville, and the Millers Creek Block, of Johnson; the Prestonburg, of Floyd; the Burnwell, Freeburn, Vulcan, and Majestic seams of the Tug Fork; and the Lower Elkhorn of the Levisa and Russell Forks. It correlates with the Warfield, No. 2 Gas, and Rowl, of West Virginia. Hitherto, the Lower Elkhorn, the excellence of which for coking was first brought to public attention by the Kentucky Survey some years ago, has been regarded as No. 3.

No. 3 (*of the old nomenclature*).—This is the Peach Orchard seam of Levisa Fork; the Alma (?) of Tug Fork; and the Alma, Peerless, and Mate Creek, of West Virginia.

No. 5 (*old nomenclature*).—This is the Upper Elkhorn of Levisa and Russell Forks; the Watson, Webb, Young, and Cherokee, of Lawrence county; the Broas Block, of Martin; and the Tracker of the Tug region in Pike. It is the Thacker, Glenalum, and Red Jacket, of West Virginia.

No. 8 (*old nomenclature*).—This is the "8-foot coal," and the Broas F. Coal, of Martin county; the Borderland coal of the Tug Fork region; and the Winifred of West Virginia and of the Borderland district in Kentucky.

The War Eagle coals of West Virginia are represented by the Elswick and Anxious creek coals of Russell and Levisa Forks in Kentucky.

Additions to the Licking Valley Report.—The delay in printing the report on the coals of the Licking Valley has not, as regards ultimate results, been without its compensations. It permitted Prof. Crandall, as the result of field work in 1908, to add materially to its value with respect to the occurrence and qualities of cannel beds in that region. It also permitted him to make revisions and additions to the Elliott county report, with respect to coals and the peridotite dikes—the latter having been the subject of much speculation and exploitation as sources of diamonds. It may be remarked here that, so far as authentic information discloses, no diamonds have been found in the dikes.

Coals of the Green River Drainage.—During the season of 1909, Mr. F. M. Hutchinson was engaged in a study of the coals of part of the region in the Green river drainage, in the Western Coalfield. Accurate work was rendered possible by the completion of the mapping of several quadrangles in that portion of the field, by the U. S. Geological Survey and the Kentucky Geological Survey acting in co-operation. Mr. Hutch-

inson was instructed to determine the number of coal beds, the average thickness, quality, dip, depth underground, and minable values of each bed, and to map, in sufficient detail for practical purposes, the areas in outcrop and below drainage of the several seams; to collect samples for analysis and for the determination of heating values, and to gather such general information as is of interest alike to the present owner and to the prospective purchaser or lessee. The quadrangles selected for the season's work were the Central City, Madisonville, Calhoun, and Newberg, embracing portions of Henderson, Daviess, Webster, McLean, Hopkins, Muhlenberg, and Ohio counties, and including an area of about 800 square miles. In addition to plotting on the topographic maps all the mines and country banks of which knowledge could be obtained, and of a large number of outcrops of coal and of other strata that may serve as "key-rocks" for the engineer employed in development work, spirit-level lines were run to each important geologic location for the determination of the average dip for each locality. The results of the season's work were very satisfactory, indeed, and have cleared up some problems in the field that have hitherto been troublesome. One of the most important results of Mr. Hutchinson's work is the definite tracing of the No. 9 coal (the most important coal, commercially, in the Western Field) across the Rough Creek Uplift, from the South to the Ohio river. The determination of considerable areas of thick coal above No. 12 is another important result, and has added materially to the value of the region for mining purposes. A summary report of the results is given in this report; the detailed report should be ready for the printer by next June.

Coals of the Tradewater Drainage, Western Field.—The study of the coals of this difficult region was placed in the hands of Dr. L. C. Glenn. Because of the many small faults, which are usually masked by the results of the erosion of the soft sandstones and shales, this region has been little understood, and the Survey has been fortunate in securing the services of Dr. Glenn, one of the most capable of geologists, for work in this field. The area embraced in Dr. Glenn's examinations covers about 500 square miles. Dr. Glenn reports that

he, also, succeeded in obtaining a connection between the coals on the south and on the north of the Rough Creek Uplift, though his determinations, in that respect, rest chiefly on drill records north of the uplift. It was not possible to prepare a summary report in time for this report; it is expected that at least a preliminary report will be ready for printing by next May or June.

Mapping Outcrop Lines in the Eastern Field.—The most needed work in the Eastern Field now is the deliniation of the outcrop lines of the mort important coals, and it is very much needed. In order that this may be done, however, more accurate topographic maps of the quadrangles included in that Field than now exist must be made. This map-work has been taken up, as part of the mapping in co-operation with the U. S. Geological Survey, and considerable progress has been made in the necessary triangulation and related work required in order to obtain "control" of the areas. Since the more precise mapping must, in the interest not only of economy but of proper methods, be carried systematically across the Field, the work has begun at the West Virginia border, the West Virginia Survey co-operating in the mapping of quadrangles that lie partly in that State and partly in Kentucky.

Oil and Natural Gas.

The widespread interest in the occurence of petroleum and natural gas in Kentucky is witnessed by the near exhaustion of the preliminary report on our oil and gas sands (Bulletin No. 1), issued in 1905. At the time the bulletin was issued, it was expected that the author, Mr. J. B. Hoeing, would continue in charge of the investigations and extend the work over all parts of the State which seemed to invite examination; but ill health intervened (finally resulting in Mr. Hoeing's withdrawal from the Survey), and, save for miscellaneous notes gathered by various members of the Survey, incidental to other investigations, field work was suspended until the past year.

In Meade and Breckenridge Counties.—Interest in the oil and gas possibilities of Meade and Breckenridge counties hav-

ing been renewed in a very marked way during the past two years, not only by residents of this State but by oil men of other States, Prof. Aug. F. Foerste was assigned to the study of the structural conditions presented by those counties with especial reference to petroleum and gas. An abstract of his report is given in this report, and it is hoped that the full report may be ready for the printer by the middle of the year; it is possible that some additional field work will be necessary, to include regions adjacent to the counties named, before a full report can be made.

In the Western Coalfield.—This is an almost virgin field for the oil and gas driller; a number of wells have been drilled here and there, but in the main they have been placed at ill-chosen points and results have been discouraging to those interested. In order to pioneer the way for drilling in an intelligent fashion in the Field, a study of the structure with reference to oil and gas was included in the work assigned to Mr. Hutchinson, the purpose being to continue the study over all parts of the Field, and to adjacent regions South, East, and West, as the work of the Survey progresses. Mr. Hutchinson is well fitted for such work within the coalfields, having been trained under one of the most accomplished geologists making a specialty of petroleum and natural gas investigations. A brief statement concerning his work during the past season is given in this report; it was not practicable for him to prepare a more comprehensive one.

In the Eastern Coalfield and South-Central District.—Work done in recent years by members of the U. S. Geological Survey and others in the oil fields of Pennsylvania, West Virginia, and Ohio has verified the observations of White, Griswold, and others that oil and gas pools may occur either along the crests or the sides of anticlines, or near the bottoms of synclines, according to local conditions, and that when the habit of accumulation in any particular sand of a given region has been determined the most likely place at which pools may be found in untested areas of that sand may be selected with a fair degree of certainty; but, in addition, it has been found that some producing sands of a given field may not show this tendency towards a definite "habit," and that in such areas the work of

the geologist in selecting places for testing is of little avail, "wild-cat" drilling being practically the only recourse. There are many oil horizons in Kentucky.* Manifestly, it is of great importance that the characteristics of the respective sands shall be known, and that underground mapping of oil-bearing beds in areas where but few test wells have been drilled, done in advance of developed pools that show close structural grouping, can be made of great value to producers in their search for new fields. In 1907 this Survey began underground mapping in Allen, Barren, Simpson, Warren, and Cumberland counties, but in consequence of the ill health of Mr. Hoeing, under whose immediate supervision the work had been placed, and of difficulties encountered in the effort to obtain the services of some other competent man, the mapping was suspended and such results as had been obtained await interpretation. It was with satisfaction, therefore, that an offer for co-operation in such work was reecived from the U. S. Geological Survey, during the past year. An allotment of $300.00, to be met by a like amount from the Federal Survey, was made for such co-operative work, and Mr. M. J. Munn, of the U. S. Geological Survey, has had supervision of the field work and will prepare the report thereon in connection with a general summary report on the oil and gas fields of the Appalachian region undertaken by the Federal organization. The oil producing areas selected for study include the Campton field of Wolfe county, and the Steubenville, Johnson Fork, Cooper, Oil Valley, and Bachelor Hollow pools of Wayne county. It is hoped that the results may justify further co-operation, and that through such arrangement similar work may be extended to other areas. Further, that the work will pave the way for a broader and more accurate application by producers of the geological principles involved in oil and gas accumulation, resulting in a corresponding reduction of the risks which, at best, must accompany the development of the great oil and gas resources of the State. Undoubtedly, if successful geological work is made possible, it will be the means of preventing the

*See Bulletin No. 1, Ky. Geological Survey, 1904.

loss of thousands of dollars in future drilling; it will obviate the necessity of drilling hundreds of useless holes, and at the same time will admit of a more thorough testing of the best oil and gas regions. Mr. Munn's summary of his work is presented elsewhere in this report.

Barytes, Calcite Lead, and Zinc.

One of the most important minerals of the State is barytes, not only with respect to commercial values but with respect to quantity. In Central Kentucky we have a district richer in such deposits of high quality than may be found, perhaps, in any other State. And yet the Kentucky deposits were so little known, before the efforts of the State Geological Survey within recent years began to bear fruit, that in accounts of barytes deposits in the United States given in technical publications, this State was no more than mentioned, if mentional at all. While the principal consumption of the mineral is for paints—and not simply as an adulterant, as some suppose, but as a useful, honest ingredient—it is used for many other purposes, among them being, glass-making, dressing for asphalt streets, rope filling, imitation marble, filler for rubber goods, porcelain and pottery enamels, enameling for papers and cardboard, the manufacture of lithophone and thus in the manufacture of oil cloths, linoleum, and rubber tires; in the form of barium hydrate for the clarification of sugar and the purification of water; in the manufacture of some of the compounds for the prevention of boiler incrustation; and so on.

Calcite is also used for a number of purposes, including the manufacture of putty and as an important ingredient of paints, the finely ground calcite (known as "whiting") being used to neutralize the acid fats in the oil in which the paint materials are mixed. One of the formulas for "white lead" calls for 10 per cent. "whiting" and 30 per cent. barytes, the remainder being made up of equal parts of lead and zinc. Considerable deposits of calcite occur in the State, one of the most notable being in Mercer county.

Accompanying barytes are galena and zinc blende, though in such minor amount that they can be produced, as a rule,

only as by-products in the mining and treatment of the barytes.

While barytes occurs to some extent in the Western fluorspar district, and in some of the south-central counties, the principal and by far the most important deposits lie within what is known as the Bluegrass Region, and since they occur in nearly vertical veins, as a rule, of which there is a surprisingly large number, they may be worked without permanent detriment to the lands, and without material temporary interference with farming operations.

The geology of the barytes-bearing rocks in Central Kentucky was reported upon by Prof. A. M. Miller, (Bulletin No. 2), and general examinations of many of the veins have been made by Mr. J. E. Wright and by the present writer;* but the detailed examination of the deposits, together with those of calcite, has been made by Mr. F. Julius Fohs, whose report is in course of preparation. Having been absent from the State on leave for the latter third of the past year, it was impracticable for him to prepare an adequate summary of his results for this report, but a brief statement is given elsewhere which will prove of interest to producers and consumers of the minerals named. It will be noted that Mr. Fohs's investigations have carried him over a large number of counties.

Waverly Formations.

Field work in the Waverly formations on the Eastern flank of the Cincinnati uplift was carried on by Mr. W. C. Morse and Prof. A. F. Foerste, in 1908, and a report was made ready for the printer in 1909. The area covered includes parts of Lewis, Greenup, Fleming, Rowan, Carter, Bath, Menefee, Morgan, Montgomery, Clark, Powell, and Estill counties. The economic values described in the report include building stones, of which the "Buena Vista" sandstone is a fine example, shales for brick, tile, and portland cement, and oil and gas horizons. Shales for common brick, drain tile, the better grades of face brick and of paving brick, roofing tile, etc., are

*See First and Second Reports of Progress.

described, and attention called to the usefulness of the black Sunbury and Devonian shales for the manufacture of cement. Samples of typical soils were collected.

Soil Survey.

This work is being carried on in co-operation with the State Agricultural Experiment Station. That portion of the investigation which has to do with the field work (including the collection of soils, the mapping and determination of the geological formations producing the soils in areas examined), with soil physics, and with fertility (pot culture) is cared for by the Survey, while the Experiment Station furnishes the soil-fertility greenhouse, the laboratories (for this work), and the soil chemists. The work is under the immediate guidance of Dr. Alfred M. Peter. So far, the burden of the Survey's part of the investigations (other than the mapping and geology) have been borne by Mr. S. C. Jone, whose practical experience, scientific training, and enthusiastic interest in his work render him peculiarly fitted for his duties. The soil survey is considered a most important part of the Survery's work, and in addition to what has been said in the bi-ennial report for 1906-'07, the following account of the methods followed (from the pen of Mr. Jones) is given: "The field operations consist of noting the native growth characteristic of the different soil areas, the length of time the latter have been under cultivation, the systems of rotation and fertilization practiced, the physical nature of the soils in the field, and the taking of samples from the different phases of soils within a geological area. This is carried on in connection with a geologist, as he works out in detail the boundaries of the various formations, thus utilizing in co-operation the knowledge of one specialized in geology with that of one specialized in soils and agriculture. The soil chemist determines the plant-food contents of the soils, their acidity, etc., which enables him in a way to suggest what elements of plant-food should be added, and also whether or not liming is necessary. A rather elaborate system of pot culture experiments has been in progress with soils which have been collected from various geological formations. The soils are taken from areas typical of the predominating types, and equal amounts are weighed out in a series of pots to which the limiting elements of plant-food (nitrogen, phosphorus, and potassium), are added in the various combinations possible. Photographs are made of the pots from time to time, and records kept of the comparative growth and yields of the different pots. Though this method of investigation is carried on under rather artificial conditions, it is felt that some very important results have been gotten, which are really an index as to what should be done in the field under natural conditions on the various soil areas. Yet we shall never feel absolutely satisfied with these results until they have been duplicated with experiment fields under natural conditions, and with different systems of rotation on the different soil areas in the State."

The making of a soil map is not a simple proposition, if the map is to be of real service, especially where there is such a diversity of soil conditions as obtain in Kentucky. In order, therefore, that a basis for an intelligent, systematic, and economical programme for the study of the soils of our more difficult formations might be obtained, areas in the Waverly, the Chester and St. Louis, and the Coal Measures were selected for study in 1908 and 1909. As representing Waverly areas where fertilizing seemed to be especially indicated, Green, Adair and Taylor counties were selected, and Mr. Jones spent the season of 1908 in those counties, the geology being determined by Prof. A. M. Miller; for the areas especially marked by Chester rocks, with St. Louis also present, Meade and Breckenridge counties were chosen; and, as a matter of economy, for certain phases of the Coal Measures, areas in the Central City and Madisonville quadrangles, in the near-by Western Coalfield, were selected for the field work of 1909. In the geologic work, Mr. Jones had the assistance of Dr. Foerste in Meade and Breckenridge counties, and that of Mr. Hutchinson in the Central City and Madisonville quadrangles. An abstract of the very useful report of Mr. Jones, covering results in the areas named, is given in this report.

According to a note furnished by Dr. A. M. Peter, more than 600 partial analyses of soil samples collected by the Sur-

vey from Western Kentucky have been made in the laboratory of the Experiment Station, and (as indicated by the report of Mr. Jones) pot experiments have been made on several types of soils. Dr. Peter considers that the most important result so far obtained in the chemical and pot experiments is that phosphate is generally needed on Western Kentucky soils, which is confirmation of the older work of the Survey and Experiment Station.

Chemistry and Technology.

During the period covered by this report, nearly 360 analyses have been made of samples collected by the Survey and sent for analysis by citizens of the State. In addition, very many specimens of rocks and minerals have been examined qualitatively for citizens of the State. As a rule, analyses of Kentucky rocks and minerals are made without charge, and it is to be regretted that a few of our citizens, taking advantage of this, have plied the Survey with samples for free analysis and then exhibited a critical spirit whenever there should be any delay in reporting results. It should be remembered that, with sincere disposition to serve every one, it is impossible for the Survey chemist to make analysis of all samples received at once; the rule of the mill must be followed. Moreover, it should be understood that unless labels accompany samples sent in we can not identify them, and they must be sent to the waste heap.

In obedience to the requirements of the law, determinations of the heating values of coals are carried on. A Parr and an Emerson calorimeter have been added to the equipment of the laboratory, and determination of b. t. u's. are made by both. This work is in the hands of Mr. R. D. Quickel, whose results for many samples are given in this report.

The testing of clays is in the hands of Prof. H. D. Easton. Some eighty burning and other tests have been made of clays from Ballard, Carlisle, Clark, Crittenden, Edmonson, Fayette, Hardin, Hart, Hopkins, Jefferson, Larue, Madison, Powell, Taylor, and Wolfe counties, representative of various types of clays and shales. Results show clays fit for many purposes,

including white ware, drain tile, No. 1 face brick, roofing and similar tile, terra cotta, fire-proofing, firebrick, etc., in addition to ordinary brick.

Professor Easton and Mr. Quickel are members of the faculty of the College of Mining Engineering of the State University, hence the work placed in their hands is carried on at much less cost to the Survey than otherwise would be the case.

One of the immediately commercially important technologic investigations conducted by the Survey, within the period covered by this report, has consisted of tests for the separation of galena from barytes in a simple way, without preliminary close sizing and yet with limitations as to minimum size of the barite fragments, with the largest possible return of clean barytes in suitable form for bleaching. The work, which was undertaken at the request of one of the Central Kentucky barytes plants, was done in the mining laboratory of the College of Mining Engineering, without cost to the Survey, by W. W. Shelby, jr., a Fellow in the College. Entirely satisfactory results were obtained, thus making available for use in grinding mills at nominal extra cost "leaded" barytes which hitherto could be used not at all or only for a very inferior "off-color" product.

Though keenly aware of the immediate and exceeding importance of the provision of the Survey law relating to an investigation of mine gases and coal dusts, I have been unable, so far, to take up that work. For it to be carried on, certain additions to the apparatus of the laboratory are necessary, and since the expenditures of the Survey have necessarily been kept within limits less than the annual appropriation, the means for the purchase of the apparatus have been lacking. It is hoped that with the coming year (1910-'11) it may be possible to undertake the investigation.

Present Limitations on Survey Operations.

Appropriations for the Survey are entered to its credit so as to conform to the State's fiscal year, July 1, to June 30. In consequence of the condition of the treasury, and in deference to the views of the Governor, $10,000 of the appropria-

tion for the year July 1, 1908, to June 30, 1909, was not used, and $5,000 of that for the year ending June 30, 1910, will not be used. This explanation is given in order that it may be understood, in the regions concerned, why plans which had been formulated for extensive topographic mapping in 1908 and 1909 have been so greatly curtailed, and why some other projected operations have been deferred. All officials concerned have given the Survey hearty support, but it has been felt desirable to keep its expenditures as low as possible without serious detriment to the service until the critical condition of the treasury could be bettered. It is expected that with the opening of the coming fiscal year the full annual appropriation may be used.

Co-operative Mapping.

In the topographic mapping carried on in co-operation with the U. S. Geological Survey, the latter meets the State Survey's allotment for such mapping with an equal amount. Under more favorable financial conditions, therefore, we would now be getting $20,000 worth of mapping annually for an annual expenditure of $10,000 (the amount authorized in the Survey act.) This would enable us to make rapid progress with the preparation of accurate maps so badly needed, especially in the Eastern Coalfield and in the southern tier of counties extending westward from the Cincinnati Southern railroad. For the reasons just given, however, the full amount of the State Survey's authorized allotment has not been used for 1908, nor will it be used during the current fiscal year. For the year 1908-'09 the sum of $3,000 was allotted (making $6,000 of Federal and State funds combined), and for the year 1909-'10, the sum of $5,000 was allotted (making a combined State and Federal allotment of $10,000.)

The programme agreed upon and carried out for 1908-'09, included the completion of the Princeton quadrangle, primary control of the Morgantown, Rochester, and Horsebranch quadrangles, and the beginning of primary triangulation for mapping Lewis and Rowan counties—the latter having less in the way of maps than any other counties in the State. In addition, triangulation for control of the Kentucky portion of the Williamson quadrangle was completed, and that for the Eastern half of the 30-minutes Prestonburg quadrangle was commenced. This carried the topographic work of 1908 over the larger part of Caldwell, a small fraction of Hopkins, and parts of Lyon, Muhlenberg, Ohio, Logan, Grayson, and Butler counties in the West; and portions of Lewis, Rowan, Carter, Greenup, Fleming, Morgan, Menefee, Bath, Martin, Johnson, Floyd, and Pike counties in the East.

The programme for 1909-'10 includes the completion of the Dawson Springs quadrangle, the completion of the 15-minute Monticello quadrangle, continuation of the primary triangulation for Lewis and Rowan counties, primary control of the Kentucky portion of the Warfield quadrangle, and primary triangulation, primary levels, and partial road traverse of one-half of the Prestonburg 30-minutes quadrangle. This carries the work over parts of Hopkins, Christian, Caldwell, and Crittenden counties in the West; over a considerable part of Wayne and over a small fraction of Russell, in the south-central region; and over parts of Rowan, Carter, Lewis, Fleming, Mason, Martin, Johnson, and Floyd counties in the East.

It is manifest that, with the comparatively small sums available for the respective years, satisfactory progress has been made. A condensed statement of the areas covered, miles of traverse run, stations set, etc., up to December 31, 1909, furnished by the Acting Director of the U. S. Geological Survey, is given elsewhere in this report.

Miscellaneous.

As part of the miscellaneous work of the Survey during the years 1908 and 1909, a number of special investigations were made at the request of various citizens. They included, among others, examinations of asphaltic sandstone in Logan county, limestones in Powell and Wolfe for use in connection with the Red river clays in the manufacture of portland cement, supposed occurrences of lead in Knox, of gold in Marion, and of silver in Menefee, also of barytes in the latter county; investigations of declining springs in Clark and Nicholas, with a view

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to finding a basis for advice as to methods that might restore their vigor; of calcite deposits in Mercer, and of lead and zinc deposits in Bourbon, with a view to preparing plans for their mining and treatment; of deposits of lithographic limestone in Meade and Bath, etc. Also, a rapid reconnoissance was made of Lewis and Rowan counties, the results of which are briefly summarized by Mr. Fohs elsewhere in this report.

Work in Progress or Projected.

Following is a brief statement of some of the work in progress or projected:

1. Continuation of the work in the coalfields, including the deliniation of the outcrop lines of the more important coals of the Eastern field as soon as the topographic mapping has advanced sufficiently.

2. A report on the structural materials and other natural resources of Rockcastle county, as representative of areas carrying the best developments of Chester and Ste. Genevieve beds in that region.

3. A report on cannels.

4. Coking tests, including experiments in blending coals. Should the latter prove successful, it will mean the extension of the life of some of the highest grade deposits many years beyond what may otherwise be their history. The investigation will require the erection of a small, practical coking oven, with necessary accessories.

5. A systematic study of water horizons, and the investigation of stream pollution. It is hoped that co-operative arrangements may be effected with the water-supply division of the Federal Survey for carrying on this work.

6. Continuation of the soil survey.

7. Continuation of oil and natural gas investigations.

8. Study of the structural materials of the State, including building stones, stone fit for lime, cement materials, etc.

9. Resumption of the field study of the clays, and continuation of burning and other tests. This will require the services of a geologist fitted for such especial work, and tentative arrangements to that end have been made.

10. A series of drill holes to prove up certain areas in the Western and Eastern Coalfields, and to make tests in the "Purchase" for oil and gas.

11. Mechanical tests of limestones and sandstones for structural purposes. A tentative arrangement for this work, with the College of Mechanical Engineering of the State University, is under consideration.

12. Revision of the report on Warren county, by the author of the original, to bring it up to date with respect to geological subdivisions and to include more recent data concerning asphalt rock, cement materials, etc.

13. Continuation of study of the Sub-Carboniferous formations.

14. Surveys of such counties as the state of topographic mapping may warrant. It should be understood, however, that, properly, the detailed county surveys can not be undertaken as a major proposition until after the more general investigations shall have been approximately completed; but it should soon be possible to take up several counties each year. When the county surveys shall be taken up in a continuous way, the Director will ask for the appointment of an advisory board.

Disbursements.

Although the Survey is credited with its appropriations according to fiscal years, the Director's reports of expenditures are required to be checked up with the Auditor's books according to quarters of the calendar year; moreover, the field plans of the Survey are necessarily adjusted to calendar years and allotments are spread so as to accord with such plans. The following report of expenditures, showing "amounts expended, under proper heads, and for what purposes," is, therefore, made up according to calendar years.

ACCOUNTS PAID IN 1908.

	Pay	Expenses	Total.
Geology.			
Salaries	$3,630.42		
Field and allied expenses		$1,118.40	$4,748.82
Soil Investigations.			
Salaries (exclusive of geologists),	300.00		
Field expenses		24.50	324.50
Chemistry and Laboratory			
Salaries	1,126.66		
Apparatus and supplies		239.46	1,366.12
Technology of Clays.			
Salaries	500.00		
Apparatus and Supplies		55.75	555.75
Oil Well Survey.			
Salaries (delayed account)	24.10		
Notary fee		.50	24.60
Office.			
Salaries, (three)	1,360.00		
Supplies, postage, telegrams, telephones, typewriter repairs, P. O. box rent, account books,		96.09	1,456.09
Drafting.			
Salary (one, three months)	375.00		375.00
Museum.			
Labor in unpacking cases and placing specimens, arranging and indexing maps, miscellaneous supplies, (soap, etc.), miscellaneous labor,		102.77	102.77
Library.			
Technical books, book-case, cataloguing books, cross-indexing books, papers, maps, etc.,		118.69	118.69
Equipment and Repairs.			
Repair of transit		.50	.50
Freights and drayage		86.10	86.10
Director.			
Pay at $25 per month,	300.00		
Traveling expenses		44.06	344.06
	$7,616.18	$1,586.82	$9,503.00
Co-operative mapping.			
Salaries, subsistence, miscellaneous expenses,			4,075.04
			$13,578.04

ACCOUNTS PAID IN 1909.

	Pay	Expenses	Total.
Geology.			
Salaries,	$3,909.92		
Field and allied expenses,		$1,754.50	$5,664.42
Soil Investigations.			
Salaries (exclusive of geologists),	919.98		
Field expenses,		172.14	1,092.12
Chemistry and Laboratory			
Salaries, (two,)	1,825.00		
Apparatus and supplies,		525.69	2,350.69
Technology of Clays.			
Salaries,	600.00		
Fuel oil for kiln,		4.50	604.50
Fuel Testing.			
Salaries,	350.00		
Field expenses, (collecting samples,)		64.55	414.55
Office.			
Salaries, (three),	1,650.00		
Supplies, 2 desks, telegrams, telephones, P. O. box rent, printed statistical sheets, postage,		181.73	1,831.73
Drafting.			
Salaries,	1,000.00		
Proof-reading of maps, drawing special map,		10.00	1,010.00
Collecting Statistics, in co-operation with U. S. Geo. Survey.			
Pay, (one man,) 6 months,	150.00		150.00
Museum.			
Indexing maps, miscellaneous work	129.85		
Supplies,		5.05	134.90
Library.			
Cataloguing, Indexing documents, etc.	70.00		70.00
Testing Laboratory.			
Springs for Shaw gas machine,		6.74	6.74
Equipment and Repairs.			
Drafting supplies, repairing tape, repairing barometers, field kit box for maps, etc., drawing board, typewriter repairs, muslin for maps, Venus pencils,		66.31	66.31
Freights and drayage,		57.40	57.40
Director.			
Pay at $25 per month,	300.00		
Traveling expenses,		21.36	321.36
	$10,904.75	$2,869.97	$13,774.72
Co-operative mapping.			
Salaries, subsistence, miscellaneous field expenses,			5,618.53
			$19,393.25

ABSTRACT FROM PRELIMINARY REPORT OF THE SOIL SURVEY.

By S. C. Jones.

Since July, 1908, the soil survey has been carried on more in detail than during previous years. In the work now being done the soils and agricultural conditions are studied in connection with the geology. For instance, a man with a knowledge of soils and agriculture works in co-operation with a geologist, and thus is enabled to know the geological origin of the various soil types and thereby determine the relation soil areas bear to geological areas.

The work is carried on either by counties or by quadrangles. In areas where the co-operative mapping has been completed, the maps show the topography of the county and the boundaries of the bottom land, etc., in such detail that work can be very much facilitated; hence it is better to work in such areas than in those of which only "plane surface" maps are at hand.

During the summer of 1908, Adair, Green and Taylor counties were gone over. These counties lie in Southern Kentucky, mainly in the Mississippian areas. In the summer of 1909, field work was confined to Western Kentucky. The early part of the summer was spent in investigating the soils and geology of Breckenridge and Meade counties, while the latter part was spent in investigating the soils and geology of the Central City and Madisonville quadrangles. These quadrangles lie in the central part of the Western Coalfield and are no doubt quite typical of this area. In this area there are hundreds of square miles of bottom land that present many problems, such as drainage, acid soils, etc. During the preliminary investigation in former years, the soils along the river and creek bottoms were excluded, since they were thought to represent the richest soils in the State and were thought to be highly productive under almost any system of cultivation, but a more detailed study reveals the fact that these soils present perplexing problems as well as those of the upland, and for this reason practically as much attention is given to them as to the upland soils.

The field operations consist of such work as outlining and

mapping the various soil areas in a county or quadrangle with a careful collection of a number of typical samples from both the surface and sub-soil of each area. At the time of taking samples, the physical nature of both the surface and sub-soil is carefully considered, as the soil exists under natural conditions in the field. Also, a careful study is made of the systems of farming and fertilization practiced, and the effects of each, judging from observation and from information obtained from farmers.

After the work of a county or quadrangle has been completed the facts observed in the field are outlined in detail in a more or less systematic order.

For instance, in a report on a county, its location is given, i. e., the portion of the State it occupies, with the number of square miles of territory within its borders, etc., with a brief description of the general geology, topography and drainage of the county. Then the soil-types occurring in the county are taken up and described in detail, giving the location in the county, the relation to other types, origin, etc., i. e., whether the soils of an area are derived from limestone, sandstone, shale, or whether derived from all these, as are many of the transported soils occurring along streams or where the geology is diversified, giving rise to soils derived from all these materials. The report also includes a detailed description of the topography of the type, with a description of the drainage, whether natural or artificial, etc. In a description of the surface soil the depth is given with the name. For instance, whether a clay, clay loam, loam, sandy loam, or sand, the name, of course, depending on the amount of clay, silt or sand predominating in a soil as is indicated by its physical nature. Color also plays a part in naming soils, as, for instance, yellow clay loam or gray sandy soil, etc. A brief description is made of the texture or granulation and physical composition, as, for instance, the kind of sand or silt composing a soil, whether fine or coarse, its compactness, perviousness to water, etc., with an estimation of the organic content as indicated from its general appearance.

In a like manner the sub-soil is described. It is sampled only to a depth of 18 inches, but is often examined to a depth

of 30 inches by means of an auger that is carried in the field at the time of sampling.

The report also includes a description of the native vegetation occurring on a soil area, with the kind of crops grown, their yields and the length of time cultivated. Also, the methods of plowing, depth, time, etc., are described with the sort of system of cultivation, whether shallow, deep or level. Such facts are considered because they are factors in conserving soil moisture, in making available plant food, and in preventing erosion or washing of soils.

Laboratory Investigations.

In connection with field investigations, laboratory work is carried on, in which chemical and physical analysis of the soils from the various soil areas are made. Along with the chemical and physical study of the soils a very elaborte system of pot culture experiments is being carried on in the soil fertility green-house at the Agricultural Experiment Station.

The laboratory investigations and pot culture experiments are carried on in co-operation with the Agricultural Experiment Station.

That portion of the investigation which has to do with field work, with soil physics and fertility (pot culture experiments) is carried on with funds furnished by the Survey, while the Experiment Station furnishes the soil fertility green-house, the laboratories and the soil chemist.

The soil samples collected by the parties in the field are sent to the Experiment Station, where the soil chemist determines their plant food content and their acidity, etc., which enables him in a way to suggest what elements of plant food should be added, and also whether or not liming is necessary.

The physical analysis of a soil consists in determining the proportions of clay, silt, and sand entering into its composition. In order to understand the problems relating to soil texture its physical characteristics must be studied. These characteristics are dependent on the dissociated particles, and the analyses are therefore of prime importance in determining and giving an understanding of different soils. In studying

soil factors in crop production, much depends on porosity and capillarity. The capacity of a soil to hold water depends upon the diameter and size of their interval surface.

To add further value to the analysis, pot culture experiments are now in progress in the new fertility green-house with soils which have been collected by the Geological Survey from various geological formations in the State. This work was also carried on last winter and many interesting results were obtained. The soils were taken from areas typical of the predominating types, and equal amounts are weighed out in a series of pots, to which the limiting elements of plant food (nitrogen, phosphorus and potassium), are added in the various combinations possible.

Manure, ground rock phosphate and ground limestone are also used.

Soils from Breckenridge and Meade Counties.

In the territory included in these two counties there is, in a general way, two great soil areas. One derived largely from a formation known as the Chester sandstone, and the other from a formation known as the St. Louis limestone. These divisions are known locally as "Sandstone and Limestone areas." Though in detail each contains within itself quite diversified geology, in a general way they may be divided into only two areas.

Corn, wheat, tobacco and hay are the principal crops grown in these counties. The average yield of corn per acre in Meade county in 1908 was 20.4 bushels; of wheat 9.3 bushels, tobacco 722 pounds, and hay, .67 tons. The average yield of corn per acre in Breckenridge county for the same year was 17.2 bushels; wheat 9.1; tobacco 721 pounds, and hay .56 tons.

These yields point to the fact that either these soils are deficient in plant food or that very poor systems of farming are employed. The real gist of the matter is that both of these

facts are true. The fact that the former is true is confirmed by a chemical analysis of the soils, which shows that they are extremely deficient in the elements, nitrogen and phosphorus. The fact that the latter is true, one may decide for himself if he will only observe and study the systems of farming now employed in these two counties.

Chemical Analysis of the Soils.

So far the chemical analysis of the soils of these counties is incomplete. The total phosphoric acid, total nitrogen and amount of lime required to neutralize the acid in these soils have been determined. The total potassium, which of course will furnish valuable information, has not yet been determined. Again, when work on the available plant food has been done, further valuable information will be furnished.

Including both surface and sub-soil, the phosphoric acid, nitrogen and lime requirements have been determined in 124 samples that were taken during the summer of 1907.

Of the 124 samples analyzed, 32 were from the surface and 16 from the sub-soil of the limestone area, while 60 were from the surface and 16 from the sub-soil of the sandstone of Chester area.

Below are given the analyses of those from the "limestone area."

SURFACE.

Sample No.	Acidity (Hopkins.)	CaO%	P_2O_5%	N%
1		.005	.101	.091
3		.002	.100	.155
5		.002	.093	.085
6		.004	.077	.057
7		.001	.154	.122
9		.002	.094	.090
11		.002	.085	.075
12		.067	.093	.085
13		.013	.068	.070

SUB-SOIL.

Sample No.	Acidity (Hopkins.)	CaO%	P_2O_5%	N%
2		.084	.097	.050
4		.034	.085	.055
8	alk.	.0022	.121	.074
10		.501	.068	.041
15		.001	.094	.077
18		.091	.070	.038
22		.013	.073	.055
27		.037	.061	.041
29		.532	.048	.041

Sample No.	Acidity (Hopkins.)	CaO%	P_2O_5%	N%
14		.002	.115	.127
16		.002	.116	.106
17		.002	.078	.096
19	alk.	.123	.070	.062
20		.001	.101	.106
21		.003	.101	.106
23		.000	.257	.208
24		.002	.051	.085
25		.030	.073	.065
26		.001	.083	.073
28		.002	.061	.082
30		.042	.060	.078
31		.051	.055	.060
42		.002	.070	.086
44		.003	.055	.078
46		.008	.087	.102
47		.002	.057	.093
49		.002	.086	.094
51	alk.	.0038	.065	.078
52		.032	.070	.042
60		.002	.086	.079
62		.014	.083	.092
79		.002	.080	.095

Sample No.	Acidity (Hopkins.)	CaO%	P_2O_5%	N%
32		.161	.053	.040
43		.041	.055	.049
45		.501	.040	.032
48		.073	.042	.056
50		.021	.073	.046
53		.223	.051	.019
61		.002	.086	.079

Below are given the analyses of the samples taken from the Sandstone area.

SURFACE.

Sample No.	Acidity (Hopkins.)	CaO%	P_2O_5%	N%
33		.001	.055	.070
35		.001	.086	.134
36	alk.	.0067	.084	.086
39		.002	.064	.073
54		.011	.055	.083
56		.003	.068	.097
57		.002	.066	.062
58		.003	.078	.094
59		.010	.088	.080
63		.003	.083	.076

SUB-SOIL.

Sample No.	Acidity (Hopkins.)	CaO%	P_2O_5%	N%
34		.013	.071	.044
37		.024	.063	.044
55		.168	.053	.035
65		.083	.061	.032
72		.130	.068	.039
74		.076	.080	.064
84		.002	.080	.074
88		.002	.064	.045
90		.002	.069	.058
94		.003	.066	.046

SURFACE.

Sample No.	CaO %	P_2O_5 %	N %
64	.006	.083	.100
66	.003	.074	.119
67	.006	.049	.093
68	.001	.048	.099
69	.017	.066	.095
70	.092	.061	.086
71	.001	.085	.075
73	.003	.090	.121
75	.016	.073	.079
76	.047	.063	.073
77	.004	.065	.117
78	.002	.088	.134
80	.002	.080	.095
81	.003	.078	.104
82	.001	.081	.081
83	.002	.096	.097
85	.002	.025	.107
86	.001	.103	.125
87	.001	.031	.093
89	.001	.080	.098
91	.003	.098	.073
92	.045	.080	.111
93	.001	.080	.102
95	.003	.083	.101
97	.004	.070	.070
98	.001	.073	.077
99	.003	.079	.123
100	.003	.089	.117
102	.002	.060	.112
103	.003	.073	.095
104	.011	.059	.070
105	.003	.074	.087
106	.003	.089	.112
107	.001	.080	.114
108	.101	.065	.099
110	.002	.049	.111
111	.003	.070	.082
112	.001	.096	.092
113	.031	.059	.068
114	.002	.045	.105
115	.002	.072	.079
117	.003	.102	.111
118	.003	.100	.114
119	.015	.074	.091

SURFACE

Sample No.	CaO %	P_2O_5 %	N %
120	.003	.071	.084
123	.003	.065	.098
124	.003	.063	.103
125	.000	.103	.098
127	.001	.084	.140

SUB-SOIL.

Sample No.	CaO %	P_2O_5 %	N %
96	.035	.065	.057
101	.006	.060	.057
109	.034	.054	.053
116	.063	.067	.049
122	.009	.066	.060
128	.002	.086	.093

It will be seen that the different samples of soil from both areas vary considerably in the percentages of phosphoric acid and nitrogen they contain, and also in the amount of lime required to neutralize the acid.

The total average of the many samples analyzed from the surface and sub-soil of these two areas bring out many interesting points as are indicated in the tabulation below.*

SURFACE SOIL.

Lime to neutralize acid.

	CaO %	P_2O_5 %	N %
Average for Limestone Soil	.0104	.0882	.086
Average for Sandstone Soil	.006	.0742	.096

SUB-SOIL.

Lime to neutralize acid.

	CaO %	P_2O_5 %	N %
Average for Limestone Soil	.154	.068	.047
Average for Sandstone Soil	.044	.067	.058

The surface and sub-soils of the limestone area are much more acid than those of the sandstone area, and in both areas the sub-soil is much more acid than the surface. Over an acre to a depth of seven inches there is approximately two million pounds of soil. Figuring on this basis it would require 208 pounds of lime to neutralize the acid in the surface of the limestone soil, while for the same amount of the sub-soil it would require 3080 pounds. To neutralize the acid in the surface of the sandstone soil would require only 12 pounds, but for the same amount of the sub-soil 880 pounds would be required.

	SURFACE.		SUB-SOIL.	
	Phos.	Nitrogen.	Phos.	Nitrogen.
Limestone soil	738 lbs.	1620 lbs.	567 lbs.	940 lbs.
Sandstone soil	638 "	1920 "	566 "	1180 "

*CaO stands for lime; P_2O_5, for phosphoric acid; N, for Nitrogen.

The surface soil of the limestone area is much richer in phosphorus than that of the sandstone area, containing 100 pounds more per acre, while the sub-soils of the two areas are practically the same. It would, of course, be expected that the limestone soil would be richer in phosphorus, since the limestone from which it is formed is largely of animal origin.

Both the surface and sub-soil of the sandstone area are much richer in nitrogen than the surface and sub-soil of the limestone area. This is probably due to the fact that the limestone area has a topography more favorable for erosion and much of the nitrogen is carried away mechanically with the soil.

Pot culture experiments are now being carried on with the soils taken from these two areas that will, no doubt, furnish much more valuable information.

Results obtained from Green, Taylor and Adair County Soils

There are a number of soil areas in these counties, derived mainly from the St. Louis, Waverly and Coal Measures formations. These areas have been mapped and the soils and agricultural conditions described. Also a number of chemical analyses have been made of both the surface and sub-soil taken from the various soil areas, and very interesting results have been obtained from pot culture experiments.

In the tabulation below are given the results of the chemical analyses of both the surface and sub-soil of five samples taken from soils derived from St. Louis formation, eight from soils derived from the Waverly, and three from soils derived from the Coal Measures. The fifth normal nitric acid solution is supposed to extract from soils the amount of potash and phosphoric acid readily available to plants, hence we have available potash (K_2O) and available phosphoric acid (P_2O_5) as shown in the following tables.

SURFACE OF ST. LOUIS.

Lab. No.	Sample No.	Acidity (Hopkins) CaO	Total K_2O	Total P_2O_5	Total N	Avail. K_2O *HNO_3	Avail. P_2O_5 *HNO_3	CaO *HNO_3
254	55	.0045	1.00	.0500	.088	.0295	trace	.125
254	61	.0045	.88	.0350	.078	.0260	.0046	.122
254	63	.035	1.10	.0625	.086	.0210	.0008	.114
254	69	.045	1.10	.0675	.104	.0475	.0030	.051
254	70	.034	1.14	.0638	.084	.0290	.0024	.089
			SURFACE OF WAVERLY.					
254	51	.0056	1.26	.0588	.102	.0155	trace	.076
254	53	.0039	1.16	.0663	.090	.0185	trace	.144
254	57	.1008	1.38	.0362	.074	.0150	trace	.054
254	59	.0036	.90	.0475	.092	.0330	.001	.108
254	71	.0022	1.85	.0638	.082	.0165	.0016	.176
254	73	.0062	1.47	.0613	.096	.0250	.0012	.080
254	79	.0045	1.12	.0875	.112	.0300	.0016	.111
254	81	.0034	1.13	.0638	.090	.0205	.0012	.108
			SURFACE OF COAL MEASURES.					
254	65	.0097	.95	.0350	.054	.0245	.0018	.054
254	69	.0056	.98	.0425	.064	.0300	.0018	.060
254	75	.0426	.67	.0488	.058	.0186	.0024	.027

*Fifth normal nitric acid solution.

SUB-SOIL OF ST. LOUIS.

Sample No.	Acidity (Hopkins)	Total K_2O	Total P_2O_5	Total N	K_2O *HNO_3	P_2O_5 *HNO_3	CaO *HNO_3
56	.0045	1.09	.0350	.045	.0435	trace	.111
62	.0616	.96	.0312	.040	.0355	.0008	.060
64	.0045	.88	.0425	.062	.0215	.0004	.136
70	.0090	1.16	.0463	.054	.0325	.0024	.098
78	.0294	1.29	.0613	.054	.0345	.0008	.089
			SUB-SOIL OF WAVERLY.				
52	.0762	1.38	.0450	.050	.0155	trace	.049
54	.0515	1.14	.0538	.048	.0290	.0004	.136
58	.1277	1.48	.0312	.044	.0160	trace	.073
60	.0056	.87	.0400	.048	.0270	.002	.084
72	.0024	1.87	.0625	.070	.0155	.0026	.157
74	.0828	1.10	.0538	.048	.0340	.0010	.046
80	.0056	1.05	.0650	.058	.0195	.0008	.117
82	.0504	1.24	.0500	.048	.0260	.0008	.080
			SUB-SOIL OF COAL MEASURES.				
66	.1014	1.26	.0400	.040	.0205	.0006	.051
68	.0655	1.13	.0375	.041	.0220	.0024	.054
76	.1232	.79	.0450	.040	.0280	.0012	.065

*Fifth normal nitric acid solution.

Below are given the averages of the St. Louis, Waverly, and Coal Measures soils expressed in per cent. and in pounds figured to the acre basis, i. e., the number of pounds of lime (CaO) required to neutralize the acid, the total number of pounds of the elements potassium, phosphorus and nitrogen, and the number of pounds of potassium and phosphorus dissolved by a fifth normal nitric acid solution.

AVERAGES FOR SURFACE SOILS.

	Acidity CaO	Total K_2O	Total P_2O_5	Total N	Avail. K_2O by *HNO_3	Avail. P_2O_5 by *HNO_3	CaO *HNN_3
St. Louis	.0044	1.04	.0557	.088	.0306	.0021	.1002
Waverly	.0162	1.28..	.0606	.092	.0217	.0008	.1079
Coal Measures	.0198	1.86	.0421	.059	.0245	.0020	.047

AVERAGE OF SUB-SOILS.

St. Louis	.0218	1.07	.0432	.051	.0338	.0008	.097
Waverly	.0502	1.26	.0528	.051	.0215	.0008	.093
Coal Measures	.0967	1.06	.0408	.040	.0235	.0012	.056

*Fifth normal nitric acid solution.

NUMBER OF POUNDS PER ACRE.

SURFACE SOIL.

	Lime to Neutralize Acid	Total K	Total P	Total N	Avail. K	Avail. P
St. Louis	88	17,264	479	1760	508	18.00
Waverly	324	21,248	521	1840	360	6.88
Coal Measures	386	14,276	362	1180	405	17.20
SUB-SOIL.						
St. Louis	436	17,762	372	1020	561	6.88
Waverly	1004	20,916	454	1020	357	6.88
Coal Measures	1934	17,596	350	800	390	10.30

The chemical analyses show that these soils, even from the same geological areas, vary quite widely in their plant food content.

The average analysis of the soils from each area shows many interesting facts. The surface soils of the Waverly

area are richest in total potassium, total phosphorus and total nitrogen, but poorest in available potassium and phosphorus as shown by the fifth normal nitric acid solution. The St. Louis soil is least acid. This is true of both the surface and sub-soil. In each area the sub-soil is more acid than the surface.

The soils of these areas are much poorer in phosphorus than those of the Chester and St. Louis areas of Breckenridge and Meade counties.

These samples show many other facts that will be brought out in the report on the soils of these counties.

Pot Culture Experiments.

For pot culture experiments, four lots of soils were taken from different soil areas. Two were taken from the Waverly formation, one from the St. Louis and one from the Coal Measures.

From each type of soil a series of pot culture experiments was carried on. Each series consisted of 17.4-gallon pots and in each pot 14,500 grains of soil were placed.

To give an idea of results obtained from culture experiments it will be necessary to include in this report the results of only one series. The soil used in this series was formed from limestone occurring near the top of the Waverly formation and is very different from the soil formed from the formation occurring near the base of the formation.

In this series the pots are numbered from 160 to 176 and plant food is added as indicated below.

No. 160 None.
" 161 None.
" 162 15 gr. $CaCO_3$ in the form of ground limestone.
" 163 6.4 gr. dried blood containing 12% nitrogen.
" 164 6.4 " " " plus 15 gr. ground limestone.
" 165 3.8 " dissolved bone containing 15% of phosphorus.
" 166 3.8 " " " plus 15 gr. ground limestone.
" 167 3.2 " potassium sulphate.
" 168 3.2 " " " plus 15 gr. ground limestone.
" 169 6.4 " dried blood plus 3.8 gr. dissolved bone.
" 170 3.8 " dissolved bone plus 3.2 gr. potassium sulphate.

" 171 6.4 " dried blood plus 3.2 gr. potassium sulphate.
" 172 6.4 " " " " 3.2 " " " plus 3.8 gr. dissolved bone.
" 173 20 gr. of rock phosphate.
" 174 35 " of dried manure.
" 175 35 " of " " plus 20 gr. rock phosphate.
" 176 35 " of " " " 20 " " " plus 15 gr. ground limestone.

The soil used in this series is a heavy loam underlain by a heavy red sub-soil. A chemical analysis shows it to be much richer in plant food than the analysis of the eight samples given above from the Waverly.

The surface soil contains 2,280 pounds of nitrogen to the acre, 1,040 pounds of phosphorus, and 21,590 pounds of potassium.

The fifth normal nitric acid solution shows an availability of 1.2 per cent. of the total phosphorus or 11.48 pounds per acre, 1.9 per cent. of total potassium or 410 pounds to the acre.

In the tabulation given below "none" means no treatment; I, means limestone; N, nitrogen; P, phosphorus; K, potassium; R, rock phosphate; and M, manure. Oats were grown in the pots and the yields are given below.

COMPARATIVE EFFECT OF FERTILIZERS.

Soil pot No.	Treatment Applied.	Straw+Oats. Gr. per pot.	Increase. Gr. per pot.	Oats. Gr. per pot.	Increase. Gr. per pot.
160	none	68	.....	10.8	.....
160	none	60.5	.....	11.1	.....
162	L.	65	.75	11.7	.75
163	N.	72	7.75	16.5	5.55
164	N. L.	58.5	— 5.75	13.5	2.55
165	P.	85	20.75	12.6	1.65
166	P. L.	95	30.75	14.5	3.55
167	K.	46	—18.25	9.3	— 1.65
168	K. L.	55	— 9.25	8.5	— 2.45
169	N. P.	128	63.75	28	17.15
170	P. K.	95	28.75	14.2	3.35
171	N. K.	75	11.25	13.5	2.55
172	N. P. K.	131	66.75	24.5	13.55
173	R.	69	4.75	13.5	2.55
174	M.	71.5	7.25	10	— .95
175	R. M.	75	10.75	15.7	4.15
176	R. M. L.	92.5	28.25	13	2.05

The increase in the yield of the pots containing the fertilizers is computed from the average yield of the duplicate unfertilized pots.

Ground limestone, nitrogen, phosphorus and rock phosphate show an increase in yield in both whole crop and grain, while potassium alone and in combination with ground limestone, shows a decrease in both. Manure alone increased the whole crop but gave a slight decrease in grain. Ground limestone and nitrogen show a decrease in total crop but an increase in grain. All other combinations show an increase in both whole crop and grain. Phosphorus alone and in combination shows in every instance a decided increase in the quantity of the whole crop, but a very slight increase in grain, except in combination with nitrogen, which causes a very marked increase. Nitrogen and phosphorus give a greater increase in grain than nitrogen, phosphorus, and potassium combined.

These results indicate that nitrogen and phosphorus should be added to this soil. The nitrogen should be obtained from the atmosphere by growing legumes, such as peas, beans, clover, or alfalfa. These crops can be fed and the manure returned or turned under directly. Phosphorus should be supplied in some condensed form as bone meal or as finely ground rock phosphate. The latter would be much cheaper and when turned under with manure or green crops would probably in the long run give as good results.

REPORT ON THE COAL BEDS OF THE TUG FORK REGION: MARTIN AND PIKE COUNTIES, KENTUCKY.

By A. R. Crandall.

Reports on the Geology of the Big Sandy river valley giving the order and dip of beds, in a general way, have been published from time to time by the State Geological Survey. Bulletin No. 4, presented the first connected view of the field as a whole, with reference to equivalency and character of rocks and of economic beds. Of necessity some localities were only partly explored, or inadequately developed by systematic work, for which time and means could not be encompassed.

Recently additional work has supplied the data for a supplemental report on the Tug Fork region, which will add much to the value of the showing in that region and will clear up some questions of equivalency of beds in this field. But consistent with what has been found in the field at large, the changes in numbers, thickness and character of economic beds of the including rocks is so great, even in this smaller field, as to make the recognition of a definite serial order of beds in some parts of the vertical section no more than a provisional standard for purposes of description.

These variations in character and thickness are well illustrated in a series of hill sections along the Tug river from Warfield in Martin county to the West Virginia line above the mouth of Knox creek in Pike county. For purposes of comparison, these sections may be placed in their distance relations in a series of diagrammatic representations of the vertical order of beds, in which some of the coal seams are readily traced in a general way at least, as representing identical geological levels. This aid in the description of the geological bed plain of the Tug Fork is given in the accompanying

Plate of vertical sections along the Tug river from Warfield to Alnwick in West Virginia.

The Warfield coal, the No. 1, of former reports, is at the base of the series of beds above the drainage level at Warfield. Drill wells in the region also show that here it is the first workable coal seam above the Conglomerate formation, the lower coarse, more or less conglomeratic, formation of the Coal Measures. This is also true of the Paintsville coal, the Prestonsburg seam, the lower Little Fork coal near Willard in Carter county, and other coal exposures that have been regarded as at the Warfield coal horizon.

The thickness of rock beds at Warfield, down to the Conglomerate formation, appears from the well record to be 441 feet. The record of a five-foot coal, 140 feet below the Warfield seam in this well is probably an error incident to oil well drilling. In other wells in the region, one or two thin coals near the 200 and 400-foot levels below the Warfield seam occur. On Cold Water Fork of Rockcastle creek a few miles West of Warfield, no coal was found. On Little Crooked branch of Wolf creek, six miles Southwest of Warfield two 2-foot coals are noted at the 210 and the 327-foot levels. These beds are important chiefly for comparison with the lower Knox creek coals of Tug Fork, the Ellswick and Auxier seams of Russell Fork and the corresponding beds on the Levisa Fork above mouth of the Russell Fork and the lower coals of the Knox creek valley, as also with the War Eagle coals in West Virginia. The interval between Coal No. 1 and the conglomerate rock is about 200 feet at Paintsville in Johnson county. In the wells previously mentioned about Warfield, this interval is increased to a maximum of 510 feet. Up the Tug river these intervening beds increase in thickness to about 900 feet at Alnwick, West Virginia, and the coal beds included also become more prominent and are increased in number, two or three becoming minable beds in the Knox creek region. The Williamson well record shows a coal bed 200 feet below the Warfield seam and a thin coal 204 feet lower. In a well on Meathouse fork of Big creek, 6 miles Southwest of Williamson, only one coal was noted above the Conglomerate beds and that at about 400 feet below the Warfield seam. These beds

are probably represented by the coal beds above the drainage at the head of the Left fork of Pawpaw creek of the Knox creek valley, about 200 feet below the Warfield seam, and the Rolly Dotson coal, 225 feet lower. These beds are 40 and 30 inches thick. Near the forks of Pawpaw, two beds are found only about 60 feet apart; the upper 42 inches (reported) probably the same as the latter, and the lower, near the creek bed showing 34 inches of coal in one bench, is about 480 feet below the Warfield seam as opened on the Right Fork.

Near the bed of Camp creek the valley next below Pawpaw creek, and about a mile from the mouth of the creek, a 41-inch bed of coal is opened under a prominent ledge of slaty sandstone, probably the upper of the last mentioned beds.

From Burnwell southward, the lower coals rise above the drainage in varying order as will be seen in the sections of the accompanying plate which, however, probably do not show all the coal seams that might be found. Two appear to mark horizons noted in oil wells in the Warfield Williamson region, mention of which has been made. They are also representatives of the War Eagle coals of Professor White's report on the coals of the upper Tug Fork valley in West Virginia.

The coal beds from the Warfield seam upward, present a variable series of minable coals, the equivalency and nomenclature of which is a matter of considerable interest aside from the special values which they give to this field from the thickness of beds and the average character of the coals.

The relation of these beds severally to beds of the same subdivision of the Coal Measures as found in the Kanawha Valley in West Virginia and in other like fields, has been the subject of considerable interest, from a laudable desire for a nomenclature of beds more suggestive than acquired local names. Observations by Dr. I. C. White, Director of the West Virginia Geological Survey, Vols. 2 and 2A, 1908, Coal Reports of that Survey, have added much comparative data in this direction, as also Professor John J. Stevenson, in an interesting paper on the "Carboniferous of the Appalachian Basin," Bulletin of the Geological Society of America, Vol. 15, pp. 37-210, and Dr. Orton, Vol. V., Ohio Geological Reports.

How far this comparative study can be made to give mining or geological significance to the name-designations of coal beds in current literature or in local use, depends very much on the view taken of the continuity of beds or how far the serial order of beds rather than definite continuity may be made the basis of nomenclature. It may be assumed that even in the great Appalachian coal field, including parts of Pennsylvania, Ohio, Maryland, West Virginia, Kentucky, Virginia, Tennessee and Alabama, a more or less comparable order of formations, and of series of beds characteristic of these formations may be recognized throughout.

But the continuity of individual beds of whatever kind over so wide and so varied a range of conditions of sedimentation as is indicated by geological features in the several States or in adjacent basins in the same State could hardly be supposed theoretically or maintained by observation. Coal seams are not exceptional as bed deposits; they increase in number and in prominence in more or less local basins and decrease in number or in thickness in adjacent basins of an equivalent series of rock beds, as found in developing the coal resources of a coal field. The recurrence of peat deposits in Carboniferous time was evidently not at successive geological levels coextensive with the Appalachian coal field, or even of the lesser fields into which it may be divided, but successive deposits in more or less local basins in such time and order as the inequalities of subsidence and of deposition may have determined; widening at some levels to overlap and increase the number of beds in the vertical section of one region, and retreating to leave a diminished number in that of another.

Rightly understood, therefore, the synchronism of beds of regions more or less widely separated by undeveloped regions, by using the same horizon-designations, should be regarded as having to do more with the comparative order of beds than with the exact equivalency or the continuity of the several beds of a series, and the value of such a nomenclature is the suggestiveness of subdivision relations as of the beds of the Kanawha series in the Kanawha Valley, and the same series in the Tug Fork valley rather than in the identity deemed more or less probable of the beds in the one field as compared

with those of the other. In the Coal Measures of Eastern Kentucky, several coal beds may be traced in a general way over the whole field, others are clearly more local in the Tug Fork region. Not all of the coal seams of the series are continuous over so limited a region, but for purposes of comparison with other fields the number and prominence of coal seams is not lacking.

In a general way, the Warfield seam, the first bed of special commercial value above the Conglomerate formation of the Lower Big Sandy Valley may be traced with such variation in character and surrounding over most if not all of the East Kentucky Coalfield. Towards the Pine Mountain it becomes the second and the third coal of importance in the series above the Conglomerate Measures. This, with the great thickening and change in the character of the rocks together with the increased dip, led formerly to the transfer of No. 1 to the next coal below (the Sicks coal, and the Auxier coal of Russell Fork), an error which is corrected by the Tug Fork sections, in which the Warfield coal is one of the pricipal horizon marks and will be described separately as the base of the series of beds which gives to the Tug Fork valley high rank as a coal region.

At Warfield, the thickness, as shown in an entry 25 to 30 feet above low water in the river or about 615 feet above tide water, was found to have a maximum thickness of five feet under a slaty shale roof.

Up the river past the mouth of Wolf creek this bed falls below the drainage or is not open to show its character and thickness.

At Borderland, nine miles above Warfield, the bed section of this seam shows prominent shale partings, which are not elsewhere characteristic of this bed; and this might be cited as evidence that it is not the Warfield seam if instances of variation equally great were not found in other beds in this region and other regions where the evidences of identity are more definite. The rock surrounding of this bed at Borderland is the usual predominating slaty shale of the lower Big Sandy valley.

The bed section at about 635 A. T. is as follows, thicknesses being stated in inches:

	Inches	Inches
Roof, slaty shale.		
Coal	13	....
Slate	....	5
Coal	18	....
Shale	....	16
Coal	9	....
Shale	....	6
Coal	23	....
	—	—
	63	27

At Williamson this bed is below the high water level. It is reached at the 24-foot depth of the Williamson drill well (see the Williamson section) at about 638 feet above tide. The identity of the seam is indicated by the continued record of this well with a coal at 200 feet, and the top of the Conglomerate measures at 550 feet.

From Williamson to Burnwell, five miles up the river, the series of beds rise rapidly and this coal takes on the features which are characteristic and unmistakable, as traced into West Virginia in the Knox creek valley and across to the waters of the Levisa Fork in Kentucky and West Virginia. This bed, the Burnwell coal, as examined in several entries, shows some variation, as in the following description:

Roof, sandrock with shale intervening in places.

	Entry No. 1.		Entry No. 2.	
	Inches.	Inches.	Inches.	Inches.
Coal	5	....	4	....
Slaty or "laminated" coal	....	5	....	8
Soft coal	16	....	....	....
Parting, barely traceable				
Splint coal	16	....	....	....
Coal with cubic fracture	23	....	46	....
	—	—	—	—
	60	5	50	8

The height of this bed above the sea is 774 above tide or 85 feet above Railway grade at Sprigg Station. The including rocks here show with increased sandstone ledges as compared with the Borderland section.

At the Freeburn mines, near the mouth of Peter creek, this seam is at 1090 A. T. (Bar.) railway grade being 727. The variations in thickness in the Peter creek valley are shown by many openings a few of which are given as an average representation.

	Freeburn Mine	Hatfield Br.	Rockhouse Fk.	Rep. by Laynes	Clark Fk.	Beech Fk Coleman's C.
Roof	Sl. to Ss.	Slate.	Slate.			Slate.
Coal	7	6	12	17		20
Slaty ("Bone")	6	5	8	7		3
Coal	46	44	54	49		40
	59	55	73	73		63

Sandrock largely predominates in the section here, cropping out in regular ledges and cliffs.

Two miles above the mouth of Peter creek (Delorme station) this coal, the Vulcan seam of the Vulcan mines, is mined on the river front. It is also opened near the head of Barren She creek. The elevation above tide at the mine entry is 1195 feet. The face of the bed at the two openings measure as follows:

	Vulcan Mine.		Barren She Opening.	
Roof	3 ft. s. to ss.		Slaty shale.	
Coal	12	....	12	....
Slaty laminated coal	....	8	....	9
Coal	54	....	54	....
	66	8	66	9

Here, as at Freeburn, the rocks above and below are cliff-forming sandstone in strong contrast, especially below, with the predominating shales in the Warfield, Wolf creek region.

Following this horizon up the river to Poplar creek the entries of the Majestic Mining Company's mines two miles up the creek, on Cow Branch and on Linn Trough branch, are at 1213 A. T., and show the following bed sections:

	Cow Branch.		Linn Trough Br.	
	Inches.	Inches.	Inches.	Inches.
Roof			8 sl. to sh.	ss.
Coal	19	....	18	....
Slaty	....	9	....	8
Coal, soft	....	....	12	....
Coal	55	....	48	....
	74	9	78	8

Ten feet above this bed on Cow branch a local 20-inch coal occurs in shales.

On Knox creek, which heads in West Virginia, a number of openings have been made, showing an increased elevation above sea level, with variations in bed section, but readily recognized as the Freeburn, Vulcan, Majestic, coal by the general features of the bed as well as by the thickness and surroundings. The following table gives some of these exposures; thickness in inches. Elevations from barometric observations and therefore only approximations.

	Elevation. A. T.	Roof.	Coal.	Slaty C.	Coal.	Total thick.
On Turkey Cr., Ferrills C.	1350	s.1 ft.to ss.	12	7	50	69
On Turkey Cr., Blankenships C.	1340	Slate	15	8	58	81
On Turkey Cr., Robnets C.	1330	Slate	12	6	43	61
Hurricane Cr., Abe Blankenship's C.	1400	ss.	12	5	46	63
Pawpaw Cr., Rt. Fk., Hurley's C.	1450	ss.	43	8	30	81
Pawpaw Cr., Mill Br. C.	1400	ss.	33	6	18	57
Lusters Fk. of Knox Cr.	1650	sl.	30	2	31	63
Black Eye Fk. of Knox Cr.	1850	ss.	25	1 to 5	35	65
Ridge bet. Long Br. of Tug and Upper Elk Fk. of Knox Cr.	1750	sl.	13	6	39	58

In the three last openings which are in West Virginia, the elevations are especially subject to corrections for variations of barometer.

The mining operations southward from Wharncliffe and War Eagle in West Virginia, are from the rapid rise of beds up the Tug river restricted to the coal seams below the Warfield bed. They are known as the War Eagle coals previously referred to.

The foot of the greater dip as shown by the preceding description of the Warfield seam is at Williamson, where it is at about 645 ft. A. T. as compared with 620 feet at the latter place, 14 miles below, considerably less for this distance than the fall of the river. Southward from Williamson the rise is 740 feet in 16 miles or an average of 46 feet to the mile. The dip is, however, increased towards the West Virginia line in the Knox creek region as will be seen from the plate of sections, so that the dip in the district from Williamson to the West Virginia line increases from 38 to 55 feet per mile.

The vertical order of coal beds at Warfield compared with that to the Northwest, have been regarded as corresponding to coals 1, 2 or 2A, 3, 5, and 6. In the region at the head of Rockcastle, a skeleton section of which is shown on the section plate, the order is the same up to coal 5; the Broas seams, coals 6 and 7, are wanting there and No. 8 is the upper seam. At Whitehouse on the Levisa fork, coals 7 and 8 appear to be represented near the top of the ridge, No. 1 below the drainage and No. 2 or 2A the cannel coal of the Whitehouse mines. The Peter Cane section, a fork of the Pigeon Roost fork of Wolf creek. The order of the beds opened appear to be Nos. 1, 2, 5 and 7. With the order indicated in the localities to the North and West, the coal horizons of the Borderland mining district may at least tentatively be regarded as representing coals No. 1, 3, 5, 6, 7, 8, and 9, the Borderland seam being No. 8. The coal beds up the Tug fork are in a general way in the same order. By the thickness and character of the three or four lower beds of Borderland, with the rise of the rock layers up the river, these seams make up the great body of coal of the region.

The following lists of names apply to these beds in different localities:

No. 1 Coal.—The Warfield, of Martin county; the Paintsville and the Millers creek block of Johnson county; the Prestonsburg seam of Floyd county; the Burnwell, Freeburn, Vulcan, and Majestic seams of the Tug Fork; and, on the Levisa and Russell Forks, the Lower Elkhorn seam. In West Virginia, the Warfield, No. 2 Gas, and Rowl.

No. 3 Coal.—The Peach Orchard seam, on the Levisa fork.

The Alma (?) seam of Tug fork. In West Virginia, the Alma Peerless and Mate creek.

No. 5 Coal.—The Watson coal of Levisa fork; Webb's and Young's coal of Cat fork, and Cherokee, in Lawrence county; the Broas Block coal of Martin county; the Thacker coal of Tug fork, and the upper Elkhorn seam of Levisa fork and of Russell fork in Pike county. In West Virginia it is the Thacker, Glenalum, and Red Jacket.

No. 8 Coal.—The "Eight-foot" coal, and F. coal of the Broas development, in Martin county; the Borderland seam of Tug Fork; and the Winifrede of West Virginia and of the Borderland district in Kentucky. Elsewhere on the Kentucky side of Tug river, this name has been applied to various beds without due regard to place in the series.

The other beds developed in this field are not so constant, or so widely developed as to be readily synchronized with coals in other regions in Kentucky.

The Williamson section of the high hill at the head of Buffalo creek, shows coals above the Winifrede, which are not included in the sections along the river in Kentucky. Back at the heads of Pond creek, Blackberry and Peter, the ridge points rise to 2200 feet or more above the sea, and include coals still higher than is included in the Buffalo creek section. Some of these are described in Bulletin 4, p. 67. Few of the ridges and spurs in which mining developments have been made rise above the 1600-ft. level. The thick coal described at the head of Pond creek (Bulletin 4, p. 67), 1200 feet above Pond creek, will be found in a few high points only; but this main ridge covers the largest area of the coals below the Borderland seam. The coal beds next above the Borderland seam, in the section at the head of Pond creek, show 36 inches or less as formerly opened by the Survey.

All the beds below and including the Borderland seam may be more or less specifically classed as caking coals; most of them vary from soft coal to splint, locally or in parts of the bed section. None appear to carry the percentage of ash usually found in block coal, excepting in the Warfield region.

The character of the product of the several beds with reference to specific commercial values cannot yet be given in

such detail as will be reached by the modern methods of testing in the practical use or by exhaustive laboratory studies.

The Warfield seam appeals to the observer as more constant in specific character than any of the beds above, but it will be noted that all are variable; perhaps nearly as much in the character of the coal as in the details of thickness and of benching by partings which must be rejected for the general market. The increase in the number of workable beds by thickening of thin seams or by the intercalation of beds, adds considerably to the coal resources southward in this field, as will be seen in the Poplar creek section.

The analyses available for giving an account of the coal of the Tug fork beds are usually such as have been made for the several mining companies by well known chemists. Samples taken under the direction of managers from the whole face represented. The unusual freedom from ash in some of the results of analyses will be remarked as probably less than the average from the personal bias of the miner in favor of the brightest chippings, but the several beds will also be noted by the unbiased observer who takes the time to examine them as now exposed in the Tug fork basin, as unusuallyy free from imbedded earthy matter.

The Warfield district is at the border of the Tug fork basin and it is not so evidently within this coking coal field. From the character of its coals as formerly mined, the Warfield seam showed a thickness of 60 inches with an upper bench of 54 inches separated from the bottom layer by a thin parting. The bed as a whole is splinty, with diffused thin earthy laminae, giving an increased per cent. of ash. A sample taken by the writer from two rooms (A) and another taken from the upper bench (B) showed the following results at the laboratory of the Survey:

		A		B
Specific gravity	1.302		1.351	
Moisture		2.00		2.16
Vol. com. matter		35.12		33.60
Fixed carbon		54.82		55.06
Ash		8.06		9.18
		100.00		100.00
Sulphur	0.983		0.745	

At the 300-foot level above the river (887 ft. A. T.) in the Warfield locality, a splint coal was formerly opened, having also a tendency to block structure, 43 inches thick. This is probably at the horizon of the Broas block, No. 5; and the Thacker seam up the river.

The results of analysis, by Dr. Robert Peter, of a sample taken by the writer from the whole face of the bed are as follows:

	Warfield 43-inch Seam.
Specific gravity	1.358
Moisture	2.50
Volatile combustible matter	33.70
Fixed carbon	52.62
Ash	11.18
	100.00
Sulphur	7.54

At Borderland, two miles above the mouth of Big creek, the three beds of commercial value are exposed below the Borderland seam. The Alma coal, 120 feet above the Warfield previously described, or at the 160-ft. level above low water, has the following bed section. Sandrock ledges are exposed above and below this seam.

	Inches.	Inches.
Roof, slate to s. s. above.		
Soft coal	50	....
Slate	....	1
Coal	10	....
Clay	....	2
Coal	3	....
	63	3

At the 260-foot level a 20-inch coal probably represents the Thacker seam. Above this coal, sandrock largely fills the interval to another thin coal, 75 feet higher in the series.

At the 410-foot level, is a bed 43 to 47 inches without parting, the lower half block coal. An entry driven in 30 feet under slate roof shows good body of coal, apparently at the

horizon of coal No. 7, as in the Whitehouse district. The Borderland seam under a massive sandrock bench near the 500-foot level has a thickness of 74 inches as measured at two headings.

This seam is in three benches of about 2 feet scarcely separated by more or less persistent layers of "mother coal." The results of analyses of this coal as given by the Manager, L. E. Armentrout, are as follows:

	Lower bench.	Middle.	Upper.
Moisture	0.68	0.79	1.49
Volatile combustible matter	35.96	36.48	33.34
Fixed carbon	61.40	59.50	60.41
Ash	1.51 reddish	2.62 white	4.19
Sulphur	.450	.610	.570
	100.000	100.000	100.000

Of the other beds no analyses are available. The upper bed as reported may be regarded as representing the Coalburg seam of the Williamson, West Virginia, section, supposed to be the Coalburg coal of the Kanawha valley.

The Burnwell section shows the order of beds as found in that district. The details of the beds are given in the vertical section. Records of developments in the neighboring hills were contributed by S. A. Beddall, Manager of the Burnwell mines.

An analysis of the Burnwell coal, the Warfield bed, by Prof. B. H. Hite, of Morgantown, West Virginia, of sample by Manager Beddall, gives the following results: Slaty 5 inches and slack not included.

Moisture	1.62	
Fixed carbon	57.72	Phosphorus, .003
Vol. com. matter	38.52	Sulphur, .540
Ash	2.14	B. T. U., 14700
	100.00	

The Alma and Thacker seams are here coking coals, and comparatively free from earthy sediment. The coal above the Thacker is the dirty or parting seam of the region, the 45-

inch bed of Borderland and the splint coal of the Buffalo creek section, W. Va.

The coal next above not seen by the writer is in the place of the Borderland seam, probably. Back in the higher region still higher coals are included, one reported by Mr. Beddall at the head of Stringtown branch, one mile below Burnwell, at the 750-foot level above the Burnwell seam (Bar), shows about 71 inches of minable coal. The Twin Knobs rise 320 feet above this level. Prominent coal stains on benches at the 650 and the 550 levels above the Warfield seam probably connect these horizons with the parting seam of the Burnwell section, and the Borderland seam 100 feet above.

The Pike Colliery seam is the Alma coal of this district, and at its maximum thickness as follows:

	Inches.	Inches.
Roof, bituminous slate to s. s.		
Coal, part splint	45	....
Shale and coal	....	6
Soft coal	18	....
	63	6

The elevation above tide is 1210 (Bar), the Railway grade at the mouth of Blackberry creek being 700 feet A. T. The mine is at the head of the Peter fork of Blackberry creek two and a half miles from the river.

Analyses of coal representing the whole bed and also the splint bench shows:

	Whole bed.	Splint.
Moisture	1.02	.860
Volatile combustible matter	37.11	36.66
Fixed carbon	56.51	56.22
Ash	5.36	6.26
	100.00	100.00
Sulphur	1.114	.715

The Freeburn Coal & Coke Co., operating at the mouth of Peter creek, are mining both the Freeburn coal (Warfield) and the Thacker seam. The former has been described at 1090

A. T. The Alma coal as opened on Hatfield branch, at 1200 A. T. (Bar.) and on Rockhouse fork at 1332 A. T. is as follows:

	Hatfield Br.		Rockhouse Fk.
Roof	Slate 4 ft. to s.s. above.		Sl. 12 in. to s.s.
Coal	27 in.	.... in.	55 in.
Clay	....	6	....
Coal	12	....	....
	39	6	55

The Thacker coal as mined in the hill to the left of Peter creek 230 feet above the Freeburn seam, 1320 A. T., shows locally two thin partings of fire-clay as below, from notes of Donald Clark.

	Inches.	Inches.
Roof, 3 feet slate to s. s.		
Coal	43	....
Fireclay	....	2
Coal	12	....
Fireclay	....	2
Coal	7	....
	62	4

This bed has been developed at a number of points in the Peter creek valleys. Representative bed sections are here given as descriptive of the bed and of its continuity in this region.

The Thacker bed.

	Rockhouse Fork.			Hatfield Br.	
	Lower Thacker.	Upper Thacker.			
	1437 A. T. (Bar)	1487 A. T.		1325 A. T.	
Roof	Bit. slate.	Slate		Sh. 6 ft. to s. s.	
Coal	66 in.	41 in.		51 in.	
Clay sl.			5 in.		Sl. 3½ in.
Coal		21 in.		15 in.	
Slate					1 in.
Coal				6 in.	
	66 in.	62 in.	5 in.	72 in.	4 in.

From analyses of the Peter creek coals made for the Freeburn Mining Company and for other parties as compiled by Donald Clark of Huntington, Manager of the Mason Coal & Coke Company, the following are selected. Analyses by Latrobe Connelsville Coal and Coke Co.

FREEBURN SEAM, MINE No. 4.

	Moisture and V. C. M.	Fixed C.	Ash.	Sul.	Coke Ash.	Coke Sul.
Pea slack	33.86	58.54	7.60	0.67	10.85	0.53
Slaty C. included	34.43	57.74	7.83	0.62	9.85	0.56
Slaty C. excluded	34.73	58.92	6.31	0.61	8.13	0.51

Whole thickness of bed 59 in. Slaty laminated part, 6 in. For coking the whole thickness would be used.

By Consolidated Coal & Coke Co., Fairmont, West Virginia.

	Moisture.	V. C. M.	Fixed C.	Ash.	Sul.
Freeburn Seam, Mine No. 4	1.80	32.32	62.82	3.26	0.83
Freeburn Seam, Mine No. 4, Coke	.30	.14	93.46	6.10	0.46
Lower Bench:					
Freeburn Seam, Mine No. 4	1.64	33.90	60.88	3.58	0.64
Freeburn Seam, Mine No. 4, Coke	.22	.42	93.26	5.10	0.58

By J. K. Anderson.—Peter Creek Coals.

	Moisture	V. C. M.	Fixed C.	Ash.	Sul.	Phosphorus.
Alma seam	0.162	35.24	57.43	6.71	0.55	.003
Freeburn seam	1.24	29.23	64.55	4.98	0.62	.....

By Mathewson. Freeburn seam, Laynes fork of Left Peter creek.

	Inches.	M. & V. C. M.	F. C.	Ash.	Sul.
Coal top	17	36.97	59.89	3.14	0.79
Coke top	17	1.73	94.05	4.22	0.42
Coal bottom	49	32.94	62.12	4.94	0.78
Coke	....	3.20	90.95	5.85	0.49
Slaty	7	31.00	52.75	16.25	0.46

The Vulcan Coal Company located one mile above the

mouth of Barren She creek has entries in both the Vulcan seam (Warfield) and the Thacker. The latter at 1459 A. T., is separated from the former by 259 feet, largely of cliff-forming sandrock.

The latter coal shows in detail:

Roof, 6 ft. or more shale to sandrock above.

	Inches.	Inches.
Coal	60	....
Clay shale	....	20
Coal	4	....
Fireclay, white plastic	....	48

The Alma coal was not examined at Vulcan.

Analysis and test by Norfolk & Western Ry. Company give the following results representing the Vulcan seam.

Moisture	1.24
Volatile combustible matter	29.23
Fixed carbon	64.55
Ash	4.98
	100.00
Sulphur	0.65
British thermal units	14665

The following are results of tests of these coals in West Virginia, Tug Fork region, as reported by Prof. I. C. White.

	B. t. u.
Average of 2 samples, Warfield seam, air dried	13909
Average of 4 samples, Alma seam, air dried	13998
Average of 6 samples, Thacker seam, air dried	13559

The working entries of Majestic mines on Poplar creek, two miles from the mouth at Cedar Station, are in the Warfield seam. The coals of the series above the Majestic Warfield bed are also exposed for examination, giving an interesting exposition of the order of beds in this district. See the Poplar creek section. The presence of the upper and lower Thacker beds as on the Left fork of Peter creek, which heads in this direction, will be noted; also the duplication of the Alma seam,

both of which features continue in the Hurricane-Turkey creek section. The parting seam above the Thacker level here offers a body of coal 85 inches thick with a parting slate of 2 inches only.

The beds above the Warfield (Elkhorn) seam are opened in the ridge at the heads of Turkey and Hurricane creeks, exposing beds as follows:

	Alma Coal	Upper Alma	Thacker Coal	Upper Thacker
H't above Warfield C. (1400' A. T.)	135' Bar.	185'	250'	315'
Roof	Cl. Sl.	Sl.	SS.	Cl. and Sl.
Coal	36"	25"	49"	32"
Parting	.....	F. C. 5"	....	Sh. ½"
Coal	.....	13"	...	15"
Tolal thickness....	36"	43"	49"	47½"

These beds rise successively to the hill tops, some of which rise above the 1900-foot level A. T., and give place to the War Eagle beds as previously described in West Virginia.

Analyses by A. S. McCreath of samples collected by J. S. Silliman from the Warfield seam in the region drained by the Hurricane, Turkey, Camp and Pawpaw creeks show the character of this seam unchanged. The results obtained are given in the following table:

	M.	V. C. M.	F. C.	Ash.	Sul.
Grassy Fork of Pawpaw	1.38	30.38	60.32	7.40	0.51
Blankenship C. Turkey Fk.	1.45	31.94	60.67	5.39	0.53
Robert C. Turkey Fk.	1.45	33.11	58.60	6.23	0.60

The average thickness of this coal in this region as shown by six openings is 62 inches of coal and 6½ inches slaty coal or 68½ inches of bed section all of which should be utilized in coking for the market. Across the ridge on the waters of the Levisa fork, this bed is equally as prominent to the West Virginia line and beyond; rising to the tops of the hills, some of which reach the 1900-foot level above sea.

In the study of this field the work has been greatly facili-

tated by the aid received from Donald Clark, Manager of the Mason Coal and Coke Co., Huntington, West Virginia, both in the field and at his office; from George Dimick, who has personally directed the study of the coal oil resources of Eastern Kentucky for many years, by records of oil wells freely offered at his office in Cattlettsburg; by courtesies extended by W. A. Young, Manager of the Freeburn mines, Roger Martin, Manager of the Vulcan Coal Company, A. B. Rawn, Manager of the Majestic Mining plant, on Poplar creek, and by S. A. Beddall, Manager at the Burnwell mines. Also by L. E. Armentrout of Borderland and A. R. Paddock of the Pike Collieries in work of a former year. Not least, by D. J. Wollford and Mrs. Wollford, who made headquarters for the season a pleasant home retreat for the writer as a representative of the Kentucky Geological Survey, at their home near the mouth of Peter creek.

COALS IN THE CENTRAL CITY, MADISONVILLE, CALHOUN AND NEWBURG QUADRANGLES OF THE WESTERN COALFIELD

By F. M. Hutchinson.

Prof. Charles J. Norwood,
Director, Kentucky Geological Survey.

Sir:

I have the honor to submit herewith the following Summary Report on the Coal Resources of the Calhoun, Central City, and Madisonville Quadrangles, and on that part of the Newburg Quadrangle lying South of the Ohio river. These quadrangles include portions of Daviess, Henderson, Webster, McLean, Hopkins, Ohio, and Muhlenberg counties, in the Western Coalfield. The area included is about 800 square miles.

The Survey is indebted in many ways to the citizens of this region generally for their cheerful co-operation in furthering the work, and especially to Messrs. Hywel Davies, Shelby Gish, P. O. McKinney, James Halstead, R. W. Batsel, and W.

P. Robertson, all of whom contributed valuable information.

Respectfully,
F. M. Hutchinson,

November 30, 1909.

Central City and Madisonville Quadrangles.

Location.—This area includes parts of Ohio, McLean, Hopkins and Muhlenberg counties, and a very small portion of Webster county, and is bounded by parallels 37°15′ and 37°30′, and by meridians 87°0′ and 87°30′. The two quadrangles being divided by the meridian of 87°15′. The area inclosed is about 460 square miles.

Topography.—In its topography this area presents the characteristic features found in the interior portions of the Western Coalfield. As a rule the hills are low, flat-topped, or oval shaped, the slopes are gentle sandy, and much eroded, and the bottoms, particularly of the large streams, are broad and flat. The most rugged topography prevails in the Eastern and Southern portions of this area, being the result of a higher general surface and a correspondingly greater erosion. In the vicinity of Bremen, Sacramento, and Anton the general surface is low, but little erosion has taken place, and the country lays well for farming purposes. Elsewhere, the above general rule applies. The configuration of the hills has been largely influenced by the predominating incoherent sandstones. The broad bottoms are due partly to the lateral swinging of their streams, but chiefly to a depression of the land, which has caused these streams to seek a higher base-level, resulting in the filling up of the old valleys to their present height. The entire area is drained by Green, Pond, and Rough rivers and their tributaries. Green river is navigable the year round, and Rough river is usually navigable for a distance above its mouth for small craft.

Culture.—There are two small cities, namely, Madisonville and Central City, and several smaller towns, among which are Livermore, Sacramento, Island, Hanson and Slaughtersville lying within these quadrangles. The railroad facilities are excellent. The St. Louis, Evansville & Nashville division of the Louisville & Nashville Railroad traverses the Western edge of this area, the Owensboro & Adairsville division of the same system, crosses it North and South near the center of the Central City Quadrangle, the Memphis and Louisvillie division of the Illinois Central crosses the southeastern corner of the area, and the new Madisonville, Hartford & Eastern Railroad extends in an east and west line across both sheets near their centers. In some localities, as for example around Sacramento, Bremen, Anton, and Madisonville, the country is in a fair state of cultivation, but generally the farming lands are sadly neglected, especially in parts of Ohio and Muhlenberg counties. Hills and sandy slopes that could profitably be kept in grass are cultivated a few years after clearing, and then cast aside to the mercy of the elements, and new land cleared. As a result, erosion has been going on at a rapid pace, and the only remedy now is to plant in grass. By far the greater part of the rich bottom lands are low and somewhat marshy, and but little attempt has been made to drain them. A systematic draining of these areas would make available some of the richest farming lands in the country.

Rocks exposed.—The rocks exposed over the area lie wholly in the Coal Measures. The vertical distance from the highest to the lowest outcroping stratum is about 650 feet.

Structure.—The structure of the Central City and Madisonville Quadrangles is rather featureless and depends mainly upon the large syncline which crosses both quadrangles in an east and west line near their centers. The bottom of this syncline enters the Central City sheet from the east at a point almost due northeast of Ceralvo, whence it extends in an almost due western course and crosses Green river at Smallhouse, thence it passes half a mile north of Bremen, crosses Pond river three-fourths of a mile south of the mouth of Log

creek, passes one mile north of Anton, and leaves the Madisonville Quadrangle at a point about two and a half miles north of the city of Madisonville.* This syncline dips to the west at an average rate of 8 feet to the mile. From its center the rocks rise both to the north and to the south. Southward they rise rather uniformly at a rate varying from 50 feet to 70 feet to the mile. To the north, however, the upward slope differs materially over the two quadrangles. Over the greater part of the Central City sheet it will average 50 feet per mile, but westward from Cypress creek, and on the Madisonville sheet, the rate of slope is much less, varying from 10 feet to 20 feet per mile.

Another structural feature worth mentioning is a small anticline which enters the Central City Quadrangle at a point two miles west of Hillside, swings to the northeast, passing about one mile north of Graham, and from thence tends to the southwest, leaving the sheet at a point lying due south of Harps Hill.

Along the northern border of the Central City Quadrangle is a fault which closely follows the general course of Rough river, probably extending as far west as Bate's Knob, and possibly farther. The downthrow of this fault is to the north and is not less than 100 feet. Another fault, or probably an offshoot of this same fault, extends from a point near Bate's Knob southward for five or six miles along Cypress creek. Both of these faults are merely parts of the great Rough Creek Disturbance of which the main fault line lies a few miles farther north.

The Coals.

But little reliable information is now available concerning the coals which lie wholly below the surface. A few widely scattered well-records, and other data, demonstrate the presence of several seams, but the knowledge at hand is insufficient to determine their thickness or quality. A test well drilled one mile north of Central City gives the thickness of coal No. 8 there as being 7 feet, but this thickness is probably due to the heavy carbonaceous shale which immediately overlies coal No. 8.

*A fault which occurs a short distance north of Madisonville has doubtless been mistaken for the bottom of the syncline; the bottom is still farther north of Madisonville.—C. J. N.

Of the coals lying below No. 8 in this region, too little is known to afford the basis of an opinion as to their thickness and character.

There are nine known coal beds outcropping on the two quadrangles. In ascending order these are, No's. 9, 10, 11, 12, 13, 14, 14a, 15 and 15a. Of these, there are four minable veins, namely, No's. 9, 11, 12 and 14, the remainder usually being too thin for profitable mining, either locally or on a large scale.

Coal No. 9.—This coal, on account of its superior qualities and minability, and wider occurrence, is by far the most valuable coal outcropping on these quadrangles. It underlies the entire area with the exception of a narrow strip about three miles wide along the northern edge of the Central City sheet, where it has been carried away by erosion. Its outcrop area is limited, however, to the southern edge of both sheets, to the hills lying immediately south of Rough river, to the vicinity of Island Station, and to the isolated hills called Bate's and Bealer's Knobs in the northwestern corner of the Central City sheet. Elsewhere over this region this coal is under cover, due to the great syncline. At Moorman it lies about 300 feet below the valleys, and at Bremen, Sacramento, Anton, and Hanson it is respectively about 350, 300, 420, and 360 feet below the drainage lines. At Slaughterville the coal is about 290 feet below the general valley level. It reaches its maximum depth at a point about midway between Hanson and Madisonville, where the syncline leaves the sheet, being then about 450 deep in the valleys. From the center of the syncline the coal rises to the north and south as has already been explained. Its maximum and minimum thickness are 6 feet and 3 feet 10 inches respectively, though at only one point, namely, in the Davis Bank west of Island Station does it reach its minimum thickness, or become less than 4 feet. It is thickest along the southern border of the two sheets, having there an average thickness of 5 feet 3 inches, but gradually becomes thinner as it extends to the north, as is the case with most of the other coals, and along the northern border has an average thickness of 4 feet 4 inches. A fair average for the whole area is 4 feet 10 inches. It is a hard, bright coal, and is almost invariably free from partings. When washed

it gives a bright, firm coke with 1 per cent. of sulphur, but when not washed, the percentage of sulphur runs rather high. It is overlain by from 2 to 5 feet of black shale which forms an excellent roof. This coal is the best shipping coal in the Western Kentucky Coalfield, as well as being now the most saleable. There are seventeen large mines in this coal now in operation on these two sheets, besides a large number of country banks which are supplying the local trade.

Coal No. 10.—Coal No. 10 is a thin vein having little or no commercial importance in this area. It ranges in thickness from 1 foot to 2 feet 6 inches, with an average of 18 inches, and attains its maximum thickness in the vicinity of South Carrollton. Usually it is found wherever No. 9 is present, being very persistent. Its distance above No. 9 varies from 50 to 85 feet.

Coal No. 11.—Next to No. 9 this coal is the most valuable coal outcroping on this area. Its areal distribution is practically the same as that of No. 9, except that it has been removed by erosion from the hills surrounding Island station, and from few smaller areas, where No. 9 still exists. Like No. 9, this coal is also thickest along the southern border of the quadrangles, having an average thickness there of 5 feet 6 inches, with a maximum and minimum of 6 feet and 5 feet respectively. It also frequently becomes thinner toward the north, being about 4 feet 6 inches along the center of the sheets, and not more than 3 feet along their northern borders. The record of a coal test made one half mile north of Hanson gives the thickness there as being 3 feet 6 inches, and a record at Slaughterville shows a thickness at that place of 6 feet 6 inches, including a clay parting of 2 feet near the middle of the seam. The quality of this coal is good, though it is softer and does not ship as well as No. 9. Usually this bed is divided into three benches by clay partings, of which one lies 18 inches above the bottom and is about 1½ inches thick, the other lies one foot below the top and is about ½ inch thick. It makes good coke, having about 1 per cent. of sulphur. Its roof is excellent, being a hard, blue limestone from 3 feet to 5 feet thick. This coal averages from 70 feet to 134 feet above No. 9.

Coal No. 12.—This coal lies at an average distance of 12 feet above No. 11 and underlies practically the same territory. It is a pure coal, rather soft and generally free from partings of consequence. It is the best coking coal known in this region, making a bright, firm coke containing less than 1 per cent. of sulphur. It attains its maximum thickness of 5 feet 9 inches in the southwestern part of the Central City sheet, and has an average thickness of 4 feet 6 inches in all the region south of the new Madisonville, Hartford & Eastern Railroad. A number of small openings have been made over this area but the coal is usually overlain by soft shale which makes a bad roof, and when possible preference is given No. 11. Locally, however, a hard sandstone overlies the coal and it forms a good roof. North of the Madisonville, Hartford & Eastern Railroad the coal is generally of little value and in places is entirely absent. Test wells made at Hanson and at Slaughterville penetrated its horizon, but found no coal at all. The only known outcrop of this coal north of this railroad is at Point Pleasant, in Ohio county. At this place the coal is 5 feet thick, and is mined for local consumption. This appears to be a local thickening of the vein, however, for nowhere else in this region was it found to be more than three feet thick. Its average distance above No. 9 ranges from 82 feet to 146 feet.

Coal No. 13.—From a commercial standpoint this coal is of minor importance. It occurs generally over the region lying south of the Madisonville, Hartford & Eastern Railroad, but no knowledge was obtained of its existence north of this railroad. No openings have been made in this coal, but from reports of coal tests its quality is good. It lies at an average distance of 150 feet above No. 9.

Coal No. 14.—This coal locally is of considerable economic importance. It is the thickest coal outcropping in this area, ranging from 5 feet to 11 feet. Its horizon underlies about one half of the Central City sheet, and about two-thirds of the Madisonville. Its southern limit may be defined as following a line which, beginning two miles south of Madisonville, from thence extends eastward, crossing Pond river near the mouth

of Bratton creek, passes through Central City, and leaves the eastern edge of this territory about one mile south of Ceralvo. Its northern area of outcrop may be traced by a line passing near Centertown, through Matanzas half way between Stroud and Island station, and thence with Cypress creek to the northern boundary of this area. These outcrop lines nearly inclose the horizon of the coal, however, for the coal itself is of a pockety nature, and is not always found where its horizon indicates its existence. For example, in Robinson's shaft, located one mile south of Moorman, the coal was 7 feet 10 inches thick, whereas at Bremen, in a test made there, it was wholly missing. Again, near Browder church, which is situated seven miles east of Madisonville, it measures 11 feet thick, but it has thinned down to 2½ feet at Hanson, and is entirely absent at Slaughterville. It is constant, however, under the hills lying between Moorman and Central City, and in the region east of Green river. Over this latter area the coal averages 7 feet 6 inches thick, and there are numerous openings which supply the local market. Generally this coal is divided into two benches by a shale parting 20 inches above the bottom, this parting ranging from 1 to 4 inches thick. It burns well, the top bench being good for blacksmithing purposes. It is used extensively as a steaming coal by the Green River packets, being pronounced the best steaming coal on Green river. It makes but little clinker, and, so far as can be told without analysis, it contains but little sulphur. Its interval above Coal No. 9 is about 220 feet.

Coal No. 14*a*.—This coal is scarcely of any economic importance. It is not a persistent vein, having been found only in the vicinity of Smallhouse, and in the hills lying south of Semiway. In the latter locality an attempt has been made to mine the coal, but failed, the coal being thin, and, as is generally the case, largely mixed with shale. It varies from 3 feet to no feet in thickness, and lies about 310 feet above No. 9.

Coal No. 15.—This coal is a persistent vein, but its area of outcrop is small. It outcrops in the hills lying immediately east of Smallhouse, surrounding Moorman, and also in the

vicinity of Gishton and Hanson. As a rule it consist mainly of carbonaceous, sheety shale, with streaks of pure coal. In places, however, as for example in the railroad cut 1 mile south of Moorman, the coal has the thickness of 16 inches. Attempts have been made to mine it in this locality, as well as in a number of places near Smallhouse, but it was abandoned on account of its thinness. Its quality was found to be good. It is overlain with from 2 to 3 feet of carbonaceous sheety shale. Its average distance above No. 9 is 340 feet.

Coal No. 15*a*.—This coal is seen in a few places in the vicinity of Gishton, and around Hanson. It is a thin vein, usually being about 1 foot thick. It is overlain with soft shale, and lies about 370 feet above No. 9.

Coals above 15*a*.—In the region surrounding Hanson are two, perhaps three coals, of which the correlation is not yet clear. They are thin veins, however, and of little economic importance. The most important is the coal mined in Jack Epply's bank located 2½ miles southeast of Hanson. At this place the coal measures 3 feet thick without parting. It has a soapstone roof. No other banks are in operation in this region, but, in a few other places, this same coal has been worked, and attempts, which were always failures, have been made to mine the other veins.

The true position of these coals will doubtless be ascertained as the investigative work is carried westward, but the data obtainable in the Madisonville Quadrangle is insufficient to show their correct correlation.

Calhoun and Newberg Quadrangles.

Location.—The area treated in this report consists of all of the Calhoun Quadrangle and about two-thirds of the Newberg Quadrangle, and is limited on the north by the Ohio river, on the south by the 37°30′ parallel, and on the east and west by the meridian of 87°15′, and 87°30′ respectively. The two quadrangles embrace portions of Henderson, Daviess, McLean, Webster, and Hopkins counties, and are separated by the parallel of 37°45′. The area inclosed is about 380 square miles.

Topography.—The topography of this area does not differ materially from that found on the Central City and Madisonville Quadrangles. The Rough Creek Uplift has left but little impression on the surface forms, though some high hills southwest of Beech Grove, the highest on this area, are due to it. The highest hills, with this exception, are found mainly in the region surrounding Cleopatra and West Louisville, and, in the southwestern corner of the Calhoun Quadrangle, lying south of Anton. The region surrounding Baskett, Zion and Coraville consists of fairly level land, excellently adapted to agricultural purposes. The extent of fluviatile deposits in this territory, on account of a body of about 75 square miles of bottom land lying between Green and Ohio rivers, surpasses that existing on the Central City and Madisonville Quadrangles, but, as a rule, low, rounded hills, and rich valleys, precisely as found on those sheets, here also prevail.

Culture.—No large towns are situated in this area, though there are a number of smaller places, chief of which are Calhoun, Rumsey, Curdsville, Beech Grove, Spottsville, and Baskett, within its borders. The country is generally in a fair state of cultivation, though much valuable farming land is uselessly allowed to wash away. That portion of Henderson county lying west of Green river embraces most of the level upland, and, except when the bottoms have been systematically tiled, this region constitutes the best farming land.

The Louisville, Henderson and St. Louis Railroad crosses the northern portion of the Newberg sheet, and the St. Louis & Nashville line of the Louisville & Nashville system crosses the extreme southwestern corner of the Calhoun Quadrangle. Green river furnishes the chief avenue of commerce for the greater part of these sheets.

Rocks Exposed.—The outcropping rocks on this area, though fewer beds are represented, are practically a continuation of the same beds found on the Central City and Madisonville Quadrangles. The sole known exceptions to this rule are seen where some of the lower rocks, as for example an exposure of Sub-Carboniferous limestone on Eyra Ashton's farm,

3 miles north of Calhoun, have been brought to the surface along the Rough Creek Uplift. Elsewhere, however, the exposed rocks all belong to the Coal Measures, the vertical section including about 300 feet.

Structure.—The principal structural features appearing in this area are two faults, which are respectively named the Curdsville Fault, and the Rough Creek Uplift. Of these the Rough Creek Fault is by far the more important. It is a well known disturbance, which extends in an irregular line almost entirely across the State, passing through Shawneetown, Sebree, Leitchfield, and further east. Its character is not everywhere known, but that portion confined to this area is in the form of a great anticline, which, under the strain of excessive folding, has been faulted or broken, in many places, with displacements varying from a few feet up to more than 100 feet. The crest of this anticline, or more properly, the centre of the Uplift, enters this region from the east at a point about 4 miles north of Calhoun, passes through Beech Grove, thence trends slightly to the southwest, and leaves the western border of the Calhoun Quadrangle at Steamport Ferry. The disturbed region is fully 4 miles wide, and, within this space, only limited areas of regularly bedded strata may be expected.

While the folding process which resulted in the Rough Creek Anticline, was in progress, the rocks along its edges were likewise subjected to an enormous strain, and when this strain had become greater than the cohesive power of the rocks, a break resulted. The Curdsville Fault is due to such a break. It apparently begins at a point near Eastwood Ferry, and from thence, with a gradually increasing displacement, which varies from a few feet at its starting point to more than 100 feet at its northern limit, extends northeastward along Green river at least as far as the town of Birk. It is probably a simple displacement of which the downthrow is to the south.

South of the Rough Creek Fault the dip of the rocks is southward toward the Great Syncline, crossing the Madisonville and Central City Quadrangles, the rate of dip being about 15 feet per mile; between the Rough Creek Fault and the Curdsville Fault, however, the general dip is to the northwest

at an average rate of 25 feet per mile. Within this area is a small syncline of which the bottom extends in a northwest and southeast line through Jolly P. O. North of the Curdsville Fault the rocks fall away to the west at a rate which varies from 15 feet to 20 feet per mile.

Coals.

No reliable data at all were obtained in regard to coals lying wholly below the drainage lines. From information obtained in other regions it is probable that a number of the lower coalt are present in this area, but nothing positive can be said in regard to their number, thickness or quality, and the drill alone can obtain this knowledge.

There are three known veins outcropping over this area. In ascending order they are Nos. 9, 11 and 12. Of these No. 9 only, except in local areas, has a reliable, minable thickness.

Coal No. 9.—This valuable coal has been removed by erosion from Green and Ohio river Bottoms, but with this exception, it underlies all that portion of Henderson, Daviess and McLean counties included within the Newberg and Calhoun Quadrangles, and lying north of the Rough Creek Anticline. In Henderson county it has an average thickness of 4 feet; in Daviess and McLean counties its average thickness is quite 4 feet 6 inches. Its quality here is generally good, varying so little from the usual type as found on the Central City and Madisonville sheets, that only a chemical analysis can show any difference at all. Commercial mines are in successful operation at Baskett, Spottsville, Bluff City, and Utopia, and many small mines, as at Zion, Coraville, West Louisville, Cleopatra, etc., which cater solely to the local market, do a flourishing business.

At Zion the coal is 115 feet deep, at Baskett 135 feet, at Spottsville 60 feet, and at West Louisville about 80 feet deep. It is drifted for near Cleopatra. In these areas the coal is invariably overlain by the characteristic carbonaceous, sheety shale, this shale forming a most excellent roof.

This coal is also found in certain small localities included

in the faulted area of the Rough Creek Uplift, but where found is usually so badly disturbed as to render successful mining on a large scale a matter of apparent impossibility. Various small banks supply the neighborhood trade, however, as, for example, in the hills southwest of Beech Grove.

The horizon of this coal also underlies those portions of Webster and Hopkins counties lying in the southwestern corner of the Calhoun Sheet, but there is some doubt as to the continuous existence of the coal itself. A test made at Slaughterville, which is situated half a mile south of the southwest corner of this sheet, found the coal to be 4 feet 6 inches thick and 300 feet deep, but a similar test at Anton naturally raises a doubt as to the existence of the coal in that vicinity, but it is needless to say that one test is insufficient to prove the facts one way or the other. The fact that No. 9 is so remarkably persistent everywhere else is a strong indication that it also exists under all this region, but further tests will have to be made before the truth is ascertained.

Coal No. 11.—This coal does not attain to minable thickness over these quadrangles except in limited areas. Its horizon may be traced, however, even where the coal is wholly absent, or exists but as a trace, practically wherever No. 9 is found, by the persistent and closely overlying limestone. In the region around Beech Grove and Delaware, and also in the vicinity of Coraville, the coal reaches a thickness varying from 18 inches to 30 inches, the average being 24 inches; and has been opened in a few places. It reaches its maximum thickness in the hills lying southeast of Hebbardsville, being there 3½ feet thick. At no other known point in this area, however, is it present in commercial thickness. Its quality is very good. Its average distance above No. 9 varies from 78 feet to 88 feet.

Coal No. 12.—This coal has but little economic value on these quadrangles. It is very persistent, however, and its areal distribution varies only an insignificant amount from that of No. 9, which has already been described. It reaches its maximum thickness in the vicinity of Anton, being there 3 feet 6 inches thick, and a number of small banks have been operated in this region for the benefit of the local trade. It has also been mined in a few places around Jolly P. O., and near

Delaware, and between Coraville and Hebbardsville, its thickness in these localities ranging from 18 inches to 30 inches, with an average of 24 inches. Its quality is good, and its roof is generally a soft sandstone. It lies at an average distance of 94 feet above No. 9.

Coals above No. 12.—Two small coals, which are probably Nos. 13 and 14, appear in the southwestern corner of the Calhoun Quadrangle, but neither is of commercial importance. The thickness of each usually ranges from 6 inches to 12 inches, with a maximum of 18 inches. No attempts have been made to mine these veins.

Ohio River Bottom

The depth of the alluvial accumulations in the broad, flat bottoms lying between Green and Ohio rivers is at least 125 feet, and probably varies from 125 feet to 150 feet. To that depth at least it is certain that no coal exists; and since the horizon of No. 9 lies from 25 feet to 75 feet above the bed of this old erosion channel, it is certain that this coal and, of course, all the higher coals, are wholly absent. The beds below No. 9, however, should not have been affected by erosion, and unless precluded by other agencies, should still be present. The only available, direct evidence bearing upon this subject is obtained from the record of a well drilled at Newman. This well was sunk to a depth of 1,200 feet, but found no trace of coal. The evidence, therefore, points to the fact that no coal exists under these bottoms, though, in an area of this size, one test, whether favorable, or unfavorable, could, of course, not be regarded as conclusive proof, either one way or the other. In this case it is highly improbable that all of the lower coals could so suddenly have been "wedged" out, and it is quite possible that some, at least, are present. There are no stratified rocks in this region, however, so the solution of the problem rests not with the geologist, but with the drill.

GENERAL SECTION.
FOR CENTRAL CITY AND OTHER QUADRANGLES.

		Thickness. Feet.
1.	Sandstone; soft, sometimes shaly; light brown; average thickness 30 feet; thickness varies	20-40
2.	Shale; sandy, brownish blue; average thickness, 8 feet	5-10
3.	Coal, 15a. Mainly carbonaceous shale, with streaks of coal; average thickness about 18 inches; varies	1-2
4.	Clay, blue; average thickness, 5 feet; varies	4-8
5.	Sandstone; soft, shaly at bottom; coarse grained, yellow, average thickness, 30 feet; varies	30-40
6.	Shale; carbonaceous, sheety; thin bedded, black, but weathering a dark blue; average thickness, 2 feet; varies	1½-2½
7.	Coal, 15. Hard, sometimes pure, sometimes shaly; average thickness, 1½ feet; varies	1-2½
8.	Fireclay and shale; blue; average thickness, 8 feet; varies	6-10
9.	Sandstone; coarse, soft, reddish brown, merging at bottom into soft, blue sandy shale	35-50
10.	Coal, 14a. Impure, not persistent; usually black shale	0-4
11.	Clay	2-3
12.	Limestone; generally in two ledges, of which the upper is about 46 inches thick and the lower 18 inches thick; very hard; steel blue on fracture; weathers into massive, irregularly-shaped boulders from 4 to 8 feet across, and of a dingy yellow color; has a granular fracture; fossiliferous	4-8
13.	Clay; heavy, light blue; makes excellent tiling	8-12
14.	Sandstone; sometimes hard, forming cliffs; sometimes soft and shaly; coarse grained, light brown	40-50
15.	Shale and "soapstone"; sometimes sandstone; soft, blue	8-12
16.	Shale; carbonaceous, soft	2-2½
17.	Coal, 14. In two benches with slate parting from 20 inches to 4 feet from the bottom; upper bench "peacock" coal, soft, makes little clinker, and has little sulphur	5-11
18.	Fireclay, blue	2-4
19.	Sandstone; usually coarse, light brown, incoherent	40-60
20.	Shale; sandy, varicolored; sometimes reddish sandstone	20-30
21.	Coal, 13. Pure, hard, bright	½-2½
22.	Clay, blue	2-3
23.	Sandstone; incoherent, coarse; brown with reddish streaks. At base of this sandstone silicious hematite is sometimes found, showing a thickness of 12 to 36 inches.	20-30
24.	Coal, 12. Bright, clean, but little sulphur; sometimes has a clay parting of 2 inches at 2 feet from bottom, but usually free from partings; rather soft	3-5½
25.	Clay, blue	3-6

		Thickness Feet
26.	Limestone; hard, blue on fracture; weathers a dull gray; usually in one large ledge, but sometimes in two or more; rich in fossils, especially crinoids	3-6
27.	Clay; sometimes hard, calcareous shale, known as "gob"	0-1
28.	Coal, 11. Bright, pure coal; ½-inch clay parting 1 foot below the top; 1½-inch clay parting 18 to 24 inches above bottom; bottom bench of coal has sulphur balls in it	3-6½
29.	Clay, light blue	3-5
30.	Sandstone; white, hard	25-35
31.	Coal, 10. Hard, pure	½-2½
32.	Sandstone; hard, grayish white, fine grained, cliff-forming; sometimes silicious blue shale	50-70
33.	Shale, gray	10-20
34.	Shale; carbonaceous, sheety, hard; sometimes contains limestone concretions of varying size	2-5
35.	Coal, 9. Pure, hard, bright, without parting; 46 inches to	5½
36.	Fireclay, blue	3-6
37.	Shale; sandy, blue	0-15
38.	Limestone; pure, soft, easily disintegrated; blue on fracture, weathers a bright yellow	1-2
39.	Sandstone; shaly, coarse grained, light brown	20-30
40.	Shale; blue, sometimes silicious	10-20

OIL, GAS, AND ASPHALT ROCK, IN MEADE AND BRECKENRIDGE COUNTIES

By Aug. F. Foerste.

About twenty years ago the inhabitants of Meade and Breckenridge counties took considerable interest in the drilling of wells for the purpose of securing natural gas. Within a few years over a hundred wells were sunk in Meade county and in the immediately adjacent part of Hardin county. Of these, the productive wells were confined to the territory between Brandenburg and West Point, nowhere extending beyond three miles south of the Ohio river. As a matter of fact, no systematic attempts to test the possibilities for gas were made outside of the limited area between Brandenburg and

West Point. Possibly ten wells were sunk in the outlying territory and none of these proved remunerative.

Several factors favored the development of the territory between Brandenburg and West Point in preference to the more southern and western parts of Meade county. The chief of these was the possibility of reaching the gas bearing strata at much less expense, although the greater proximity of this territory to the natural market, Louisville, also was an important factor.

The gas was obtained in the Black Shale, forming the upper part of the Devonian section of the rocks of Kentucky. Along the river bottom lands within a mile of Brandenburg, this Black Shale could be reached by wells about 500 feet in depth. At Long Branch, about four miles east of Brandenburg, wells between 400 and 425 feet in depth were sufficient. At Rock Haven, the Black shale was struck at about 360 feet below the river bottoms. About two miles east of Rock Haven, it was reached at 325 feet; and at West Point, at about 270 feet.

From this it is evident that the level of the Black Shale rises eastward and dips westward. In consequence of this westward dip the Black Shale is not struck at Richardson's Landing, a mile above King's Landing, and six miles west of Brandenburg, until a depth of about 800 feet is reached. It is calculated that at Concordia, in the western edge of Meade county, a depth of 1120 feet would be necessary to reach the Black Shale. Southwestward, along the Ohio river, this depth increases. At Stephensport, in the northwestern part of Breckenridge county, the Black Shale was struck at a depth of 1234 feet. It is estimated that at Cloverport a depth of about 1250 feet would be necessary.

From this it is evident that even if gas could be obtained from the Black Shale horizon in the territory west of Brandenburg, the wells bored east of Brandenburg would be more remunerative, and the latter territory would be exploited first. The expense of drilling a well naturally increases in a much greater ratio than the depth.

If the drilling were begun not in the river bottoms but upon the hill tops, the necessary depth of the well would be increased by an amount equal to the height of the hill. Since the hills along the Ohio river in Meade and Breckenridge counties are frequently 200 feet in height, and the surface rises to 300 feet above the river bottoms within two or three miles of the river, the expense of reaching the Black Shale horizon rapidly increases. The result has been that up to date little attempt has been made to test the Black Shale horizon west or south of the Brandenburg-West Point territory.

The dip of the Black Shale has not been determined with accuracy. West of a line connecting Concordia with Hardinsburg, the dip is chiefly westward. East of this line, for a short distance, the dip is a little north or west. Along the line connecting King's Landing with Harned, the dip is estimated as approximately twenty degrees north of west. Farther east the dip has not been worked out very well, but is known to be westerly. Between West Point and Stithton, it appears to be south of west.

The rate of dip between West Point and Brandenburg is about 20 feet per mile westward. This dip is not equally distributed. Between the Bickerstaff wells at Long Branch and Brandenburg, the dip is 35 feet per mile westward, and then for a short distance east of the Bickerstaff wells the dip is about 10 feet per mile in the opposite direction, eastward. In other words, there is a small arch or incline at Long Branch, whose axis probably extends across the Ohio river in a direction a little east of north and from which the strata dip east and west. This arch has been called the Davis arch, after Mr. W. J. Davis, who first recognized its presence. Between Long Branch and West Point the dip is about 17 feet per mile westward. From this it is evident that the Davis arch is merely a local flexure interrupting the general westerly dip of the strata in this part of the county.

Although the Davis arch is a flexure of only small dimensions, its presence appears to have favored the accumulation of gas in the vicinity of Long Branch. Whenever water and gas are present in the same strata, the gas tends to rise above the water level, and wherever the strata are bent into the form of an arch, the gas tends to rise toward the most elevated part of the arch, toward the axis. If any of the overlying strata

consist of clay, or other comparatively impervious material, the rise of the gas is checked at the clay layer, and tends to accumulate along the axis of the arch just beneath the clay layer.

It happens that in Meade, Breckenridge, and other counties of Western Kentucky, the Black Shale is directly overlaid by a clay horizon, known as the New Providence clay shale in Indiana. Beneath this clay shale, the natural gas has accumulated along the Davis arch, and that is why the wells of the Brandenburg-West Point area must be drilled through the New Providence clay shale horizon, into the Black Shale, in order to tap the accumulations of natural gas.

Since the Davis arch is of small width and height, the amount of accumulation of gas beneath the New Providence clay shales of this arch is comparatively small, and this supply can be readily exhausted. As a matter of fact, this exhaustion has already begun. Pumping is necessary to keep the wells free from water, and during the summer of 1909 pumping was observed at only two wells, along the line between the Bickerstaff and Baskett farms, at Long Branch. At these wells, the pressure appeared to be low. The difficulty of securing reliable information from those most directly concerned in the exploiting of this natural gas supply is very suggestive of an insufficient supply, since a company supplied with an abundant supply of gas need not fear publicity.

Since the Black Shale dips toward the West, it must rise toward the East. Sooner or later it must crop out at the surface of the ground. As a matter of fact, the Black Shale outcrops along a belt crossing the middle parts of Jefferson and Bullitt counties in an approximately north and south line. Along this line of outcrop no natural gas could be expected, since the cover of New Providence clay shale has been removed and the gas may escape freely. Even for a considerable number of miles west of the line of outcrop, the conditions would not favor any considerable accumulation of gas, especially in the absence of any distinct arch of considerable dimensions. The eastward rise of strata favors the escape of the gas from beneath cover.

One of the earliest wells drilled in the Brandenburg-West

Point field is located on the Moreman farm, about a mile east of Brandenburg. This well was bored in 1863. The gas, as elsewhere in this field, is accompanied by salt water. For a number of years, the gas was used in evaporating the water and thus securing the salt. At first only five barrels a day was secured, but, at $5.00 a barrel, it paid. Later, when by improved methods the yield had been increased to twenty-five barrels a day, the price sank to 50 cents, and even to 45 cents a barrel, and finally the work was abandoned. In the meantime the pressure of the gas had decreased considerably. Similar salt works, started two miles northeast of Rock Haven, also are abandoned at present.

At present, the only wells actually in use are in the possession of a company engaged in supplying the citizens of Louisville with gas for heating purposes. In addition to this, the company controls other wells in the immediate vicinity, which it no longer utilizes.

Since the heating company supplying gas for fuel purposes to the citizens of Louisville is at present the only company utilizing the gas, private enterprise is not tempted to exploit the field any farther. Gas might be secured, but it could be sold to the Louisville company only at its own terms. A second company, interested in the same project, has found it impossible to secure the right of way to Louisville under any conditions which would make the enterprise profitable. Brandenburg and West Point might use up some of the gas, if further drilling discovered additional productive wells, but these towns are small and the prospect is not alluring. Possibly the Kosmos Cement plant, along the Ohio river a number of miles northeast of West Point, could make use of natural gas in sufficient quantities to make the field profitable, if it could be revived. The distance to which it would be necessary to convey the gas would be much less and the expense for this part of the service would be less.

In Breckenridge county, gas in paying quantities was discovered at Cloverport, on the Ohio river. Twenty years ago a dozen wells were in existence, practically within the town limits. A number of these wells were productive. Originally the pressure was good, but in recent years the pressure went

down to such an extent that the wells were practically abandoned for a time. At present, three of the wells are in use. At the tile works, in the eastern edge of the town, there is enough gas to run two boilers. The pressure here is about 65 pounds. The well along the river bank, immediately west of the mouth of Clover creek, has a pressure of 55 pounds, and produces whatever gas is used in Cloverport at present. This gas is utilized only in the western half of the town, west of Clover creek. Another productive well occurs about a square farther west, also on the river bank, behind the Mill. The pressure here is considerably less than 55 pounds, but pumping operations are continued, and this relieves the neighboring wells of water. When pumped out, the gas supply is fair. When pumping is stopped, the water soon drowns out the gas. The overload of water is too great for the gas to lift with facility, and the gas practically stops flowing. A well, seven squares south of the mill, once furnished considerable gas. Another, two or three squares south of the depot, on the eastern bank of Clover creek, once was a good well, but now is covered with water.

The recent revival of interest in these wells is due to Mr. Otto Tague. This gentleman has illustrated the value of expert knowledge in propositions of this nature. A field, once abandoned, has been converted into a source of modest revenue. Several wells have been freed from water, and properly connected with the mains. The pressure has been adjusted so as not to endanger the premises of the citizens using the gas. A part of the gas is utilized to illuminate the streets of the town. Eventually, it is intended to open up several additional wells, long abandoned, and to connect also the eastern half of Cloverport with these wells. It is intended to drill several additional wells. Should the hopes of the company now controlling the wells be realized, there might be sufficient gas to supply Hawesville, a small town, in a direct line about 8 miles northeast of Cloverport.

Both the well behind the grist mill and the well at the tile factory had not been used for about two years. After water had been pumped from the well from behind the grist mill for 30 days, the pressure rose to 65 pounds, but began to drop as

soon as pumping operations were discontinued. The well at the tile factory has recently been cleaned out and recased. The well at the mouth of Clover creek, the income of which had been reduced to $15 a month, under present conditions supplies a revenue of $150 a month. A contract has been made to supply 50 gas lamps for illuminating the streets of Cloverport at $1,000 per year.

The depth of the wells at Cloverport is about 900 feet. Since the Black Shale horizon at Cloverport is estimated to lie about 1350 feet below the level of the town, it is evident that the source of the gas at this locality must be from a considerably higher horizon than the Black shale. This source is either in the lower part of the St. Louis limestone, or in the upper part of the Keokuk formation. Judging from the records of the Stephensport well, this horizon at Cloverport belongs to the lower part of the St. Louis limestone formation. However, several speciments of rock said to have been obtained from one of the wells more closely resembles the rather coarse-grained limestone forming the underlying Harrodsburg limestone horizon. Only a continuous series of samples, such as that secured from the Stephensport well, can definitely determine the exact geological horizon.

If the Harrodsburg horizon has not been attained, in the Cloverport wells, it would be advisable to continue drilling until this lower horizon was reached. A coarse-grained limestone, such as the Harrodsburg limestone, if sufficiently thick, is likely to prove a better reservoir for gas that a finer, denser grained limestone, such as the St. Louis limestone.

The horizon at which the gas at Cloverport is found is approximately 450 feet above that at which the gas in the Brandenburg-West Point area occurs. Since none of the wells at Cloverport reach the Black Shale horizon, this estimate evidently is based on a comparison of various intermediate sections, chiefly that of the Stephensport well.

If the upper part of the Harrodsburg limestone serves as the reservoir for the gas at Cloverport, the very fine-grained limestone forming the St. Louis formation may serve as the cover. Between the Harrodsburg limestone and the St. Louis limestone, however, in Northern Kentucky and Southern In-

diana, is a clayey horizon, the Atherton bed. This bed belongs above the typical Salem limestone, which in Indiana is found immediately above the Harrodsburg limestone. The order of succession of these strata, in descending order, is:

St. Louis limestone.
Atherton bed, chiefly clay.
Salem limestone, of Indiana.
Harrodsburg limestone.

The Salem limestone is an important formation in the central part of Indiana, but it thins out southward to only two to four feet along the Ohio river. It has not been recognized in Kentucky. The overlying Atherton bed, however, carrying about the same fauna, is well represented in Northern Kentucky, but thins out before reaching Central Indiana. This Atherton clay bed may furnish the dark rock immediately overlying the coarse-grained Harrodsburg limestone of the Stephensport section. If present at Cloverport, it would serve as a cover beneath which the gas would accumulate.

If those interested in gas and oil wells were to preserve well labeled samples of their well drillings, taken every ten or twenty feet, a great part of the guessing made necessary under present conditions would be unnecessary, and underground geology could be placed on a much securer footing.

The conditions which favored the accumulation of gas in the Cloverport area appear to have been a small local flexure, similar to the one near Long Branch, in the Brandenburg-West Point area. The top of the limestone layer, which at Cloverport occurs about 30 feet above the level of the railroad, is found at railroad level at the Little Tar Spring, about two miles west of Cloverport. This is a westward dip of about 15 feet per mile. The westerly dip probably continues at least for several miles west of the Little Tar Spring, although the river takes a directly northward course. Hence, the top of the limestone exposed above the railroad level at Cloverport reaches river level a short distance below the mouth of Millstone creek, on the Indiana side of the Ohio river.

About four miles East of Hawesville, a fault appears to

bring the basal sandstone and conglomerates of the Coal Measures down to railroad level. On the Indiana side of the Ohio river, this basal Coal Measure conglomerate is found more than a hundred feet higher up, near the top of the hills.

Southeast of Cloverport, there is a dip toward the southeast. This dip may be determined along both roads to Harrodsburg, the one north of Clover creek, and the one south of this creek. The dip amounts to about 30 feet within half a mile, toward the southeast, and then for another half mile or mile the strata are approximately horizontal.

These facts suggest the presence of a local flexure of the strata in the western part of Breckenridge county, forming a small arch with its axis at Cloverport. As in the case of the Davis arch, no great accumulation of gas can be expected here, although careful conservation of all the gas supplied by the various wells might yield considerable revenue on an economical basis of expenditure.

In general, the strata in the western part of Breckenridge county dip westward. Between Hardinsburg and Cloverport, this dip averages about 26 feet per mile. Locally, this dip varies considerably in direction and amount, indicating that local flextures occur also in the intermediate area. A fault, of only moderate proportions, was noticed about four miles southeast of Cloverport, along the western end of the road connecting the two roads leading to Hardinsburg.

In case of both the Cloverport arch and the Davis arch near Long Branch, the western flank of the arch presents a long westward dip, while the eastward dip of the eastern flank is short. Possibly the source of supply of gas in both cases lies toward the west of the axis of the arch, and the flexure merely retards the escape of the gas eastward. The water in the depression east of the axis, where the eastward rise of the strata forming the arch is resumed, may act as a sort of plug, retaining the gas to a certain extent.

This question of the original source of the gas is of interest since it may be connected with the question as to origin of the oil and so-called tar products found in various parts of Breckenridge, and in some of the neighboring counties.

As far as the data so far accumulated may indicate, no ac-

cumulations of oil in any large proportions are to be expected in Breckenridge, or in any of the immediately adjacent counties. It is very unsafe, of course, to make any predictions, since the entire history of oil well digging appears to be a succession of discoveries of valuable reservoirs of oil at most unexpected places, but the evidence so far accumulated does not give the prospector great encouragement in the area under discussion.

Nevertheless, small accumulations of oil have been struck at various localities, and these accumulations appear to increase in number and quantity toward the west.

In 1889, a well was drilled immediately east of Hawesville, for gas. At a depth of 1230 feet, oil was struck. Since gas, and not oil, was wanted, drilling continued down to a depth of 1500 feet. By this time about $3750 had been expended, and no signs of gas in paying quantities had been discovered. Discouraged in the search for gas, the well was filled up to the level at which oil had been struck, and then was shot. The flow of oil increased. A tank for receiving this oil was built in the immediate vicinity. The oil was used for lubricating purposes. The amount shipped was somewhere between 50 and 100 barrels, and the total supply obtained amounted to about 200 barrels. A number of years were spent in slowly developing this well, and most of the pumping of the oil was done in 1895, or 1896. A second well was begun in 1893. The boring was discontinued at a depth of 900 feet. A third well was begun in 1904. At a depth of 300 or 400 feet, the drill got struck, and the well was abandoned.

About four miles east of Hawesville, on the Indiana side of the Ohio river, oil was struck at the home of Mrs. Mason, just above the mouth of Deer creek. At present no reliable data are obtainable, but it is known that the supply amounted to a number of barrels, and that more could have been obtained. Gas, not oil, was wanted.

In the absence of samples from the wells at Hawesville and at the mouth of Deer creek, it is not possible to determine at what horizon oil was struck at either locality.

Tar Spring is located about three miles directly south of Cloverport. Here the water rising from beneath the Tar Spring

sandstone carries with it a small quantity of oil, associated with which is the dark-brown, sticky substance that has given rise to the name, Tar Spring. It is evident that this so-called tar is the residual part of the oil after the more volatile parts of the oil have evaporated. To that extent, it indicates the presence of oil in the vicinity of Cloverport. A similar spring, known as the Little Tar Spring, occurs along the railroad track, about two miles west of Cloverport.

The source of this oil is unknown. The sandstone may be serving as a reservoir, rather than as an original source of the oil. Near the line of outcrop of this standstone, not much oil could be expected. Wells should be sunk a considerable distance west of the line of outcrop, where this sandstone is well under cover of the overlying clays.

At Cloverport, the base of the Tar Spring sandstone occurs about 30 feet above the level of the railroad. About 70 feet below the level of the railroad at the same locality, the top of the Garfield sandstone should be found. About two miles south of Garfield that sandstone has become so thoroughly impregnated with the more solid parts of the oil that the sandstone has been converted into an asphalt rock. Oil must have seeped through the sandstone for long ages, losing the more volatile parts by evaporation toward the surface of the line of exposure. Such an accumulation of asphalt can be regarded only as a residual product, from oil. The local distribution of this asphalt suggests that the sandstone may have served merely as a channel along which the oil seeped gradually upward. The same original source may have supplied both the Garfield and the Tar Springs sandstone.

The Garfield sandstone is separated from the underlying Big Clifty sandstone only by a comparatively thin limestone bed. In Grayson county, both east and west of Leitchfield, the Big Clifty sandstone is impregnated locally with asphalt.

The fact that the asphalt is already mixed with sandstone suggested twenty years ago the advisability of trying the rock as a road metal. It appeared to serve this purpose very well, but the commercial success of the enterprise was not encour-

aging,* and for many years, the so-called asphalt mines of Garfield have remained idle, and those of Grayson county appear to be about ready to suspend operation.

Occasionally, a little oil has been found in the wells drilled for oil in Meade county.

West of Cedar Grove church, about a mile south of Weldon, an oil well was sunk in 1888. A rather poor flow of gas was reached at a depth of 719 feet. This well was cleared out near the close of 1908. At about 860 feet, salt water was struck, and this rose to a height of 300 feet in the well. The quantity of this water, however, was small, so that the well was easily kept dry by bailing. The bottom of the Black Shale was said to have been reached at a depth of 934 feet. This may be true, since at a depth of 973 feet, salt water rose in large quantities, to a height of 180 feet from the top of the well, causing the abandonment of further drilling. Since this water appeared to come from a rather coarse grained limestone, apparently from the upper part of the Devonian limestone horizon, the rock at 943 feet may have been from the basal part of the Devonian Black Shale. Those engaged in drilling the well thought they had reached the top of the Black Shale at 700 feet. This would give a thickness of 243 feet to the Black Shale, an amount believed to be in excess of the facts. At a depth of 755 feet, a gritty layer was struck, yielding a slight increase in the flow of gas and a small quantity of oil. Although the rate of flow of this oil was very slow, it finally rose to a height of 400 feet above the bottom of the well. Two more of these gritty layers were struck at lower levels, in going through the so-called Black Shale. The upper gritty layer evidently consisted of a coarse-grained limestone, since it dissolved readily in hydrochloric acid. Its horizon probably was in the lower part of the New Providence clay shale, instead of in the Devonian Black Shale. This may have been true also of the underlying gritty layers, whose exact horizon has not been recorded.

Recently the well on the farm belonging to Jack and Harry

* Which, however, was in no way related to the character of the material, or its fitness for road-making.—C. J. N.

Herrington, about two and a half miles south of Weldon, was noticed to have 3 or 4 inches of oil on top of the water which gradually had filled the well. After removing the oil, it gradually accumulated again. This well had originaly been a gas well, sufficient gas having been obtained to supply the house. The well was drilled in the eighties.

Similar discoveries of small quantities of oil at other wells encouraged some of the citizens of Meade county to make an attempt to secure oil, in place of gas. It was hoped that this oil might be obtained by going beneath the Black Shale, into the so-called sand which had been reached in the Weldon well. This so-called sand was merely the coarse-grained limestone beneath the Black Shale, but the term sand is used by oil drillers indiscriminately for any coarse-grained rock, apparently presenting a loose texture.

Knowing that oil, like gas, tends to rise towards the top of anticlines or arches in the rock, the citizens interested in the oil well project made search for an anticline, and came to the conclusion that the conspicuous hill ridge two miles south of Ekron, was produced by such an anticline, that the presence of the high hill was in itself an evidence of the presence of such an anticline. While this line of reasoning is entirely incorrect, it happens, as a matter of fact, that a small anticline is present in the region traversed by the ridge, but this anticline is small both in height and in width, and does not give promise of yielding any great supply of oil, even if any should be discovered. It is merely a local flexure in the general westward dip of the rocks of this part of the county, comparable with the local flexures at Long Branch and at Cloverport. Believing that the hill itself was the anticline, the well was started on the very crest of the hill ridge, thus unnecessarily adding about 300 feet to the depth of the well to be bored. It has not been found possible to secure reliable information from those engaged in this enterprise, and no oil had been discovered when the territory was last visited, late in the summer of 1909.

If all the facts which have been revealed by the drill during the last twenty years could have been made available, the work of drilling for gas or oil could have been placed upon a much more intelligible basis. The geologist can learn some-

thing from exposures as they occur at the surface. Often he is driven to form conclusions from facts derived solely from this source. But it is evident, that the driller is interested chiefly in the geology of the strata not exposed to view, hundreds, and even thousands of feet beneath the surface. If all the facts, derived from all the wells could be collated, underground geology by this time would be on a rather fair footing. The tendency on the part of drillers to conceal the facts simply prolongs the days of comparative ignorance. Ignorance on their own part as well as ignorance on the part of others. The rights of the prospector are protected sufficiently well by his leases. The ultimate result of the secrecy observed by many drillers results frequently in the concealment of ignorance rather than in the accumulation of information. The numerous associations among men engaged in other lines of business illustrate the fact that a comparison of the experience secured by many men in the same line of business is helpful to the entire fraternity. This lesson has not yet been learned by many of those engaged in prospecting for oil.

A number of references have been made to the well at Stephensport. This is the only well in Meade and Breckenridge counties from which a consecutive series of samples appears to have been collected in an intelligent manner. As a result, more has been learned from this single well than from any of the remainder. The following notes will present some of the chief features of this well record.

Limestone fragments, 22 and 30 feet beneath the surface of the ground at the opening of the well, indicate the presence of a layer of limestone below the Garfield sandstone, and above the Big Clifty sandstone.

Fragments of the Big Clifty sandstone were struck 35 feet below the surface.

Fragments of Ohara limestone were brought up from levels 48, 67, 75, 85, 130, 135, 155 feet below the top of the well. Some of this limestone was coarsely grained, especially toward the top. Some of it was fine grained. Toward the base, sandy particles were imbedded in the limestone. The limestone usually is of a whitish color.

Oolitic grains, indicating the presence of the Fredonia

limestone, were brought up from depths of 200, 230, 240, 260, and 280 feet below the top of the well.

The St. Louis limestone is fine-grained, and usually is of a distinctly grayish color. Samples were brought up from depths of 300, 350, 370, 380, 395, 420, 435, 450, 460, 475, 482, 500, 510, 515, 530, 535, 540, 555, 585, 600, 620, 630, 638, 644, 650, 656, 662, 668, 680, 686, 692, and 712 feet below the top of the well.

At 735 feet below the top, a rather coarse-grained limestone was struck. At 755 feet, a medium-grained dark gray rock. At 780, a fine-grained dark gray rock. At 786, this dark gray rock was medium-grained in part. At 786, 807, 813, 840, and 860, more of this dark gray rock was struck. Most of this was fine-grained, although more medium-grained particles also occurred. This represents a thickness of 125 feet of rock, of which a part at least may belong to the Atherton horizon.

At 890, the coarse-grained limestones begin, and these are present also at depths of 900, 915, 960, 1000, 1030, and 1045 feet below the top. A minimum thickness of 155 feet of coarse-grained rock is present, which probably represents the Harrodsburg limestone horizon.

Medium-grained light gray rock occurs at depths of 1050, 1080, and 1100 feet. Fine-grained rock occurs at levels of 1124, 1127, and 1130, 1138, 1150, 1155, 1185, 1230 feet below the top of the well. This total thickness of 180 feet is regarded as representing the equivalents of the Knobstone formation. If this view be correct, the Knobstone has thinned out very much westward. The upper, medium-grained part may represent the Brooks bed, and the lower, fine-grained part includes the New Providence clay shale.

The typical Devonian Black Shale is represented by fragments from depths of 1234, 1253, 1315, and 1319 feet. At this depth, 85 feet below the top of the Black Shale, further drilling was abandoned.

An interpretation of these records suggests the following succession of strata, given in descending order.

Garfield sandstone, not exposed in the well.	
Clover-creek limestone, better exposed on the river bank....	11 ft.
Big Clifty sandstone, about	18 ft.

Ohara limestone, about ..... 107 ft.
Rosiclaire sandstone, may be represented by the sandy particles near the bottom of this limestone.
Fredonia limestone, oolitic, about ..... 145 ft.
St. Louis limestone, fine-grained, about ..... 455 ft.
Atherton bed may be represented in part by the darker rock ..... 105 ft.
Harrodsburg limestone ..... 155 ft.
Knobstone, including both the Brooks and the New Providence divisions ..... 185 ft.
Black Shale, penetrated to a depth of 85 ft. Total thickness unknown.

At Stephensport, at the mouth of Clover creek, the upper part of the limestone overlying the Big Clifty sandstone is exposed. A thickness of at least 11 feet is observed. The overlying strata are exposed along the roads going up the hill, both north and southeast of the town. In descending order, the following strata are exposed.

Tar Springs bed, consisting chiefly of sandstone.
Only the lower part is exposed. Southeast of the town the following subdivisions are noted:
Massive sandstone ..... 22 ft.
Chiefly clayey and shaly beds with a little limestone near the middle ..... 38 ft.
Stephensport bed; chiefly two limestone horizons separated by an intermediate clay horizon, which near the middle may be replaced by shaly or even by massive sandstone layers. Southeast of town, the following subdivisions are noted:
Upper-limestone, containing large pentremites ..... 24 ft.
Clay ..... 16 ft.
Sandy layers ..... 14 ft.
Poorly exposed, probably chiefly shaly sandstone ..... 15 ft.
Lower limestone, oolitic toward the top ..... 26 ft.
Garfield bed, consisting chiefly of sandstone, but locally replaced to a considerable extent by clay. The total thickness of this bed is ..... 127 ft.
Southeast of town, the upper 44 feet of this bed consists of clay. Along the road north of town, this upper part consists chiefly of shaly sandstone layers, underlaid by clay, and this in turn by sandstone. Clay also occurs near the middle of the Garfield bed, and sandstone at the base, the intermediate part not being well exposed.

Clover-creek limestone is exposed at the mouth of Clover creek. The thickness may equal 15 feet, but the actual exposure is ..... 11 ft.
Big Clifty sandstone, not exposed, but struck in the well.

The Big Clifty sandstone is not exposed here. Where typically exposed, this sandstone is one of the most important in the series of rocks belonging to the lower part of the Carboniferous system. Judging from the well at Stephensport, the Big Clifty is reduced to a very small thickness at Stephensport. This is true certainly of the actual exposures in the vicinity of Sample, four miles east of Stephensport.

These sections at Stephensport, both the one actually exposed, and the one traversed by the well, will serve to indicate the relative position of the strata discussed in connection with the oil and gas wells of Meade and Breckenridge. A much greater accumulation of facts is at hand, and will form the subject of a more extended report.

PRELIMINARY REPORT ON OIL AND GAS POSSIBILITIES IN THE NEWBERG, CALHOUN, CENTRAL CITY AND MADISONVILLE QUADRANGLES, INCLUDING A DISCUSSION OF THE PRIMARY FACTORS GOVERNING SUCH ACCUMULATIONS

By F. M. Hutchinson.

Primary Factors necessary for an accumulation of Oil and Gas.—Practical work in many oil fields has demonstrated that four primary factors are instrumental in forming a valuable accumulation of oil and gas. These are: (1) A porous rock. (2) An impervious cover. (3) Water. (4) Favorable geologic structure.

1. *Porous Rock.* By a porous rock is meant one in which the pores are of sufficient size to permit of the passage of oil downward, or upward, or laterally as the case may be. Such a rock is usually a sandstone, but may be a limestone, shale or

any sedimentary rock. The need of a porous stratum is obvious, for in the minutely diffused state in which oil was originally formed it was wholly valueless, and consequently there must be some avenue of escape from its original resting-place to some point of concentration. Doubtless there are no absolutely non-porous rocks in nature, but there are many so dense as not to fall within the pale of the above definition. Further, there are no perfectly homogeneous rocks in nature, and many relatively non-porous areas occur in an otherwise porous stratum. These impervious areas afford more or less impassable barriers to the passage of oil, and constitute, for that particular place, the highest or lowest point in the porous rock. It is obvious that the amount of oil any rock can contain varies with its thickness and porosity.

2. *The Impervious Cover.* Over all oil-rocks in which valuable accumulations have been found is a relatively impervious stratum, through which the oil and gas will not pass even when subjected to an enormous pressure. This impervious stratum serves as a cover to retain these fluids in the underlying geologic reservoirs, and usually consists of a dense limestone or shale. Its need is obvious for without it the oil and gas would rise to the surface and be wasted.

3. *Water.* All oil-bearing rocks at the time of deposition were wholly saturated with water, of which by far the greater part was salt-water, this condition being due to the fact that sea-water, in which the rocks were deposited, is a strong brine. This briny condition, however, has probably had nothing whatever to do with the accumulations of oil and gas, water alone being the requisite.

Most oil-bearing rocks, however, are now partially dry, having in some mysterious way lost a portion of the inclosed water, but it is probable that most oil and gas pools were largely formed under conditions of complete saturation. This is a debatable point, but in any event the action of the water as an aid in forming the accumulations has very likely been the same.

Just what this action has been is a subject upon which all geologists do not agree, but the balance of evidence seems to indicate that the water has acted both as a heavier-than-oil

fluid, and as an agency of collection. Assuming this statement to be a fact, it is an easy matter to imagine the progress of a tiny globule of oil from the time it first became free to move in the oil bearing stratum, until it reached its final destination. At first it rose, say, from the bottom of the rock until stopped in its upward course by the impervious cover at the top, this action being due wholly to the fact that its specific gravity was less than that of the enveloping water. Arriving at the top of the rock it would indefinitely remain unless acted upon by some force other than gravity, since it is hardly probable that the globules of oil gathered together in this way could more than fill the irregularities in the roof of the rock. The water, however, is in motion, or sooner or later is set in motion, due probably to the crumpling of the earth's crust, but possibly to unequal heating, or the escape of water in one place, or its entrance at another, but, whatever the cause, it is sufficient that the water became in motion. Being in motion it would obviously collect the various globules of oil along its course, and carry them forward until arrested by some geologic reservoir, the highest within reach. Here, though the two substances had become mixed in transit, the heavier weight of the water would cause it to descend to the bottom, and the oil would be forced to the top.

4. *Favorable Geologic Structure.* By favorable geologic structure is meant such structure of the rocks as will tend to act as a reservoir, and retain the products of large areas within relatively small limits. A complete discussion of the various forms of structure as they affect the concentration of oil and gas may be found in the works of Orton, White, Griswold, and others, and will be included in the full report on the above named quadrangles now in course of preparation. For the purposes of this paper it is thought sufficient to give the principal places of accumulation, of oil and gas, which are as follows:* (1) In dry rocks the principal points of accumulation of oil will be at or near the bottom of the synclines, or

* NOTE—The paragraphs in regard to "principal places of accumulation," except for a modification of the last two paragraphs, was taken literally from Bul. 318, U. S. Geol. Sur., pp. 13, by W. T. Griswold.

at the lowest point of the porous medium, or at any point where the slope of the rock is not sufficient to overcome the friction, such as structural terraces or benches. (2) In porous rocks completely saturated the accumulations of both oil and gas will be in the anticlines, or along the level portions of the structure. Where the area of porous rocks is limited the accumulations will occur at the highest point of the porous medium, and where areas of impervious rocks exist in a generally porous stratum the accumulation will take place below such impervious stop, which is really the top limit of the porous rock. (3) In porous rocks that are only partly filled with water the oil accumulates at the upper limit of the saturated area. This limit of saturation traces a level line around the sides of each structural basin, but the height of this line may vary greatly in adjacent basins and in different sands of the same basin.

Partial saturation is the condition most generally found, in which case accumulations of oil may occur anywhere with reference to the geologic structure; it is most likely, however, to occur upon terraces or levels, as these places are favorable to accumulation in both dry and saturated rocks. Under all conditions the most probable locations for the accumulations of gas, which is the lightest of the three fluids, are on or near the crests of anticlines, though small folds, which are really small anticlines, along the sides of a syncline may hold a small supply of gas. The rocks may be so dense, however, that the gas can not travel to the anticline, but will remain in volume close to the oil. If any medium lighter in specific gravity than oil, but heavier than gas, as, for example, water vapor, exists in the rocks, the gas will rise above this medium, and be separated by it from the oil.

The statements given above are based on the assumption that the rocks have not been disturbed by faulting. The effect of faults on possible accumulations contained in the Newberg, Calhoun, Central City, and Madisonville Quadrangles, is hereinafter noted.

Sands.

The St. Louis limestone underlies these quadrangles at an

estimated depth of about 1,600 feet below No. 9 coal, and wells drilling below this depth would probably encounter only a succession of limestones. Oil may exist in these limestones, but it is probable that drilling through them now, in absolutely untested territory, would be a mere waste of money. The Trenton limestone, which is the best known oil-bearing limestone, lies at a depth of from 4,000 to 5,000 feet, in Western Kentucky, and is of course entirely too deep for profitable drilling.

Above the St. Louis limestone, however, are four or five sands, ranging in thickness from 10 feet to 60 feet, and any one or all of them, may contain accumulations of oil and gas.

Deep Wells.

No oil or gas pools have been found in these quadrangles, and only a very few test wells have been drilled. A well was drilled to a depth of 1,200 feet at Newman, in the Newberg Quadrangle, but no oil or gas was reported as being found. This well started in Ohio river alluvium, below the horizon of No. 9 coal, and encountered only a succession of sandstones, clays and shales. Four wells have been sunk to reported depths of six or seven hundred feet along the crest of the Rough Creek Anticline, three being situated 2 miles north of Calhoun, and one at Beech Grove, and in each of these wells a small quantity of oil and gas was found. As is hereinafter explained, however, only limited quantities of either of these fluids could have been expected within this badly disturbed area. No records of these wells have been obtained so far, and it is possible that none exist. Some four or five deep wells were drilled about one mile north of Central City, and a little oil and gas was found. But little information could be secured about the records of these wells, though two or three were reported as having been drilled to a depth of 1,400 feet. These wells start between coals No. 13 and No. 14. The Dun Oil Co. drilled a well 1,200 feet deep on the Elvis Bell farm 3 miles northwest of Sacramento, but no oil or gas was reported. It has not been possible to secure a record of this well. It starts near the horizon of No. 14 coal.

It is needless to say that these wells constitute practically no test whatever for these great areas, and for all oil and gas purposes these quadrangles may still be regarded as virgin territory.

Faults and Their Effects on Oil and Gas Accumulations.

Small quantities of oil and gas have been found in various places within the disturbed areas known as the Rough Creek Uplift. Two miles north of Calhoun is a spring from which a small quantity of oil has been issuing from a time which antedates the memory of the community's oldest inhabitants. A number of bore holes near this spring have also struck a like quantity of oil. At Beech Grove is a well 180 feet deep from which a gallon or so of oil is obtained daily, and a deep well, near the same town, obtained about the same amount. Most of the above mentioned wells also furnished a small supply of gas.

Now the question that confronts the practical oil man is this: Are these small flows of oil and gas indications of a larger supply near at hand of which only the outer edge, so to speak, has been penetrated?

It may be said in the beginning that the possibility of finding a rich pool of either oil or gas within the region affected by this fault is small indeed. It is quite possible that these "shows" of oil and gas are indications of former great pools in these vicinities, but the violent cataclysm which wrought the upheaval of this great anticlinal opened huge fissures, perhaps miles in length, along its top; and if oil will escape from a 10-inch hole at a rate of thousands of barrels per day, and gas at a rate running up into millions of cubic feet, how much more readily would it not issue from these enormous natural vents? Obviously, however large the former supply may have been it has long since been wasted, and the little that is found now is probably but a seepage of the small supply that lurked behind.

What is true of the Rough Creek Fault, is also true of the Curdsville Fault, and of the Fault south of Livermore, though in the latter cases a much smaller area is disturbed. It would

be well in drilling, however, to keep a mile or so away from these faults.

Favorable Oil and Gas Territory.

Of the four factors governing the accumulation of oil and gas, only structure can be determined in advance of the drill. Since adequate drilling to decide the nature and extent of the three remaining factors in the Newberg, Calhoun, Madisonville, and Central City Quadrangles has not been done, the possibilities of oil and gas in these quadrangles will be treated simply as regards the structural conditions presented.

The Moorman Syncline affords the best large territory for possible oil accumulations. Into this great basin, unless impeded by saltwater, the oil would flow from wide areas extending several miles to the North, to the South and to the East. Anywhere along its bottom from the point where it enters the eastern edge of the Central City Sheet, near Ceralvo, until it leaves the Madisonville Sheet, between Hanson and the city of Madisonville, may be considered as favorable territory. To secure a thorough test of all the sands the wells here should be drilled not less than 1,600 feet below No. 9 coal.

The small quantities of oil secured along the top of the Rough Creek Anticline indicate the probable former presence of a large supply within this region. Doubtless more or less of this oil was wasted when the faulting occurred, but it is probable that some of it flowed "down hill," so to speak, along the dip of the rocks to the North and to the South of the disturbed area, and may exist in quantity not far from its border lines. Anywhere within a mile or so of the southern and northern border lines may be regarded as likely territory. Near Jolly P. O. is a small syncline which could serve as an excellent reservoir for this soil, and this syncline is considered the best location on any of the quadrangles for a test well. The Newberg Quadrangle is generally flat and presents no very favorable structural conditions for either oil or gas.

Unfortunately, there are no areas in these quadrangles which can truly be called favorable gas territory from a structural standpoint. The small anticline lying to the southeast

of Earles, along the southern border of the Central City and Madisonville Quadrangles, may hold a good supply of gas. Elsewhere the most favorable structural areas are in the vicinities of Centretown, and Cleaton, and in the southeastern corner of the Central City Quadrangle, and about 2 miles southeast of West Louisville in the Calhoun Quadrangle.

OIL AND GAS FIELDS OF EASTERN AND SOUTH CENTRAL KENTUCKY

By M. J. Munn.

Prof. C. J. Norwood,
Director, Kentucky Geological Survey,
Lexington, Ky.

Dear Sir:

I have the honor to submit below a brief statement of the work done and the funds expended to date in the examination of the oil and gas fields of Eastern Kentucky.

This work was undertaken, in connection with that for a summary report on the oil and gas fields of the Appalachian region, by the United States Geological Survey. The Kentucky Geological Survey allotted the sum of $300 to be met by an equal amount from the U. S. Geological Survey for the purpose of affording a more detailed study of certain of these pools than could otherwise have been done. The special object of this work was to determine the relationship of these pools to the anticlines and synclines of the oil bearing beds, and to see if a knowledge of the structure thus obtained can be made of value to the producer in his work of developing these natural resources.

Work done in recent years by the United States Geological Survey in the oil fields of Pennsylvania, Ohio and West Virginia, has demonstrated the fact that many large pools of oil in those States show a very marked tendency to group themselves along the crests or sides of anticlines in such a manner

that when once the "habit" of accumulation of oil and gas in a given sand is determined in one locality the position of other still undiscovered pools in that sand can be closely estimated when the dip of the rocks is carefully mapped. By this work of the U. S. Geological Survey, pools in other oil sands were found to show no evidence of structural arrangement, and thus, geologic work can prove of little value in locating undiscovered pools in those sands. It is therefore of great importance to producers to know into which of these classes the oil pools of Kentucky fall, since that region seems destined in the future to receive increased attention from them, in their search for new pools. For this purpose I have selected certain tpyical fields in Eastern Kentucky, and have collected data with which the anticlines and synclines of the oil bearing beds may be carefully mapped. Spirit level lines were run to a large number of wells in and around these producing areas. With these levels the elevation above sea level of the mouths of wells were secured. Records giving the measured depth to the top of the oil or gas bearing bed were obtained from the owners, and the position of each well plotted on a map. With this material the exact shape of the oil bearing sand can be computed and represented on the map. The elevations above sea level of certain outcropping beds have also been secured and plotted with which it will be possible to determine approximately the degree of convergence existing between it and the oil sands and thus secure a reasonable basis for calculating the dip of the oil sands from a study of the surface rocks in areas where no wells have been drilled.

The areas thus studied in detail are the Campton oil field of Wolfe county, in which the Clinton sand is oil bearing, and the Steubenville, Johnson's Fork, Bachelor Hollow, Oil Valley, and Cooper pools of Wayne county where the Beaver creek and shallow sands are productive. In addition to this somewhat detailed study, a briefer examination has been made of the Ragland field, of Bath county, the Menefee county gas fields, the Irvine oil field of Estill county, and the Parmleyville, Mt. Pisgah, Slickford, Sunnybrook and Parnell pools of Wayne county, maps of most of which will be published.

I have had as levelman and general field assistant Mr. M.

W. Crouch, Topographic Draftsman, and have also employed two rodmen from time to time as the work demanded.

The field work done for this report during the months of October and November involved an expenditure of about $438, three hundred dollars of which is charged to the co-operative fund referred to above. The remainder was paid by the U. S. Geological Survey from the funds for a summary bulletin of the oil fields of the entire State.

The results of the work cannot at present be definitely determined since a suitable base map must yet be drawn in the office from material collected in the field, and the oil data plotted thereon, before the exact structural position of the pools can be determined. I estimate that between two and three months will be required in the office for one man to prepare the maps and text for this report. A bulletin containing this material will be submitted for publication as soon as the data can be prepared.

Very respectfully,
M. J. MUNN,
Geologist.

U. S. Geological Survey,
Washington, D. C., December 13, 1909.

THE BARYTES AND ASSOCIATED DEPOSITS OF CENTRAL KENTUCKY

BY F. JULIUS FOHS.

The following covers briefly the results of the investigation of these deposits to date:

Barytes occurs in Central Kentucky in three forms of deposits: Veins, Bed-veins, and Geodes. Of these only veins are of economic importance; occasionally a bed-vein might prove so.

1. *Veins.* By these are meant vertical or slightly inclined tabular deposits, which pinch and swell on following the dip

or strike. These may reach a maximum depth of 1,200 feet or more, a maximum in length of 4 miles or more, and a width of 12 feet or more, in Central Kentucky. As much of the strata may be eroded, the average known depth of a majority of the deposits is 600 feet, and how much deeper is not known, at least half of which carries a commercial product. The average which varies from 2 to 4 feet. These veins fill three types of fissures: Simple fissures; shift faults (displacement of walls lengthwise of vein and characterized by horizontal slickensiding and vertical walls); and normal faults (vertical displacement and irregular dip of walls). Simple fissures occur only occasionally. Shift faults are the common type in Central Kentucky and roughly parallel the axis of the Cincinnati Anticline. Normal faults carry deposits of good quality but not as frequently as shift faults in Central Kentucky. Zones of roughly parallel faults of either type occur one-half to one mile or more wide.

Barytes occurs in Kentucky alone or associated with fluorspar and calcite; to a minor extent, zinc blende and galena are found with these minerals. Barytes ranges through the entire known stratigraphic series of the State from the base of the Campnelson limestone of the Ordovician to well up into the Coal Measures. It is lacking in some of the beds, but this is due to selective deposition rather than to the lack of barium-bearing solutions penetrating such beds. Limestone is preferably the home of barytes and the associated minerals; quartzite or chert breccias are occasionally so; the least favorable of all are the shale beds. It is because of the preponderance of shale in the Cincinnatian series that it carries so little barytes; where suitable limestone beds occur in it, the barytes occurs also. In Central Kentucky, the richest deposits occur in the Lexington limestone and the next in value are those in the Winchester and the High Bridge limestones.

Fluorspar, in Central Kentucky, is not confined to the High Bridge limestones, but may be associated with the barytes at any horizon; however, it appears largely restricted to local areas—the Boone's Creek region, involving parts of Fayette and Clark counties, and the Mundy's Landing region, involv-

ing parts of Mercer and Woodford counties. It is in the latter area that calcite finds its maximum development.

Lead and zinc, chiefly as sulphides, are to be had as by-products in barytes mining, often in sufficient quantity to add materially to the profits, but the lack of proper milling facilities has prevented much being realized from this source. An occasional deposit may be expected in which the percentage of these metallic minerals may be sufficient to mine as a primary source of profit, though such instances are likely to be rare.

Barytes is the predominant mineral in Central Kentucky, with calcite next and then fluorspar; while zinc blende and galena make up the remaining smaller percentage of the deposits.

The origin of the deposits is a mooted question of which little of definite value has been learned. This much, however, having a practical bearing, has been determined: That the bulk of the barytes was deposited prior to the deposition of fluorspar and calcite and that there was a minor deposition of barytes after the fluorspar and calcite were deposited. This gave the barytes freeest play in deposition and left lesser spaces for the deposition of fluorspar and calcite. Where several or all of these minerals were present in a solution, precipitation took place in the order of their solubility beginning with the least soluble; barytes, fluorspar, galena, zinc blende and calcite. As a necessary corallary, barytes required the least amount of a precipitation force, and calcite the greatest. Hence it is that we find the barytes filling open cavities wherever they were to be found, fluorspar or fluorspar and calcite filling any remaining or later formed cavities, whereas galena, zinc blende and calcite are usually found in the less open parts of the veins (where they pinch, are filled with breccia or a horse, or have narrowed to a seam necessitating the spreading of the solutions into the wall rock thereby replacing the latter), where the circulation is necessarily restricted and where the greatest precipitating force was active, such as stagnation or impounding of solutions.

It will not be out of place to state here the results of a recent comparative study of the country rocks found inclosing

the best fluorspar shoots of the mines of the Kentucky-Illinois district. These facts taken in connection with what has previously been said regarding the likely relations of barytes and the associated minerals in the veins will no doubt be suggestive of what may be anticipated where a certain set of conditions is had, in the veins of either Western or Central Kentucky. The study in question showed that good fluorspar shoots are found in fifteen different combinations of geological formation-members. The shoots were directly the result of a combination of several or all of the following features of the wall rocks. Nos. 1, 2, and 3 are usually found in one wall, 4 and 5 in the opposite wall, while 6 affects both walls:

1. Open texture.
   a. porosity, b. lamination, c. shearage, d. brecciation.
2. Ready solubility.
   a. absence of clay. b. easy removal of impurities.
3. Ready interchange of elements of wall rock for those of solution (replacement).
4. Impermeable barrier.
   a. shale. b. clay gouge, c. compact limestone.
5. Presence of hydrocarbons.
6. Extent of displacement.
   a. different wall rocks. b. juxtaposed concavities.

Of these, the first three conditions are most necessary for replacement deposits, the last three for open fissure fillings.

2. *Bed-veins.* These usually result from the cementing brecciated limestones which have shrunk upon dolomitization or partial leaching. These are represented by the zinc deposits in the Devonic-Siluric limestones of Lewis county, also to be seen in Nelson and Oldham counties; by a bed of the St. Louis-Keokuk limestone brecciated and cemented with barytes in Estill and Menefee counties; and by a bed of Richmond limestone brecciated and cemented with zinc blende, gypsum, barytes and calcite in Lincoln county.

3. *Geodes.* Geodes bearing the minerals under consideration have been found notably in the Winchester limestone, in some of the Upper Cincinnatian limestones, in the Keokuk limestone and in the Waverly sandstones.

The only veins found thus far cutting Devonian slates in

Kentucky consist of narrow seams of quartz, or of pyrite, or of pyrite in a siliceous breccia. In southwestern Marion county are found faults in connection with small anticlinal and synclinal folds in the Keokuk limestone; in one case the breccia was cemented with gypsum and pyrite, and in nearby joints traces of lead and zinc are said to have been found. These occurrences are not of commercial interest.

The result of investigation, by counties, after having spent from a day to a month or more in a county as it may have required, of the barytes and associated minerals of the State outside of the Western Kentucky lead, zinc, and spar district is as follows:

Counties carrying veins, many of which are worthy of development are the following, (investigations have been completed in those counties here marked by an asterisk, in the others the work is in varying stages of completion); these counties all form part of the Central Kentucky district.

County.	No. of Veins.	On Farms.	County	No. of Veins.	On Farms.
Anderson	5	6	*Jessamine	12	40
Bourbon	25	6	*Lincoln	10	10
*Boyle	20	32	Madison	1	2
Clark	4	8	*Mercer	8	26
*Cumberland	1	1	*Monroe	1	1
*Fayette	32	47	Owen	2	4
Franklin	4	4	*Russell	1	1
*Garrard	11	25	Scott	9	10
*Harrison	2	4	Woodford	15	21
Henry	7	7			

Total, 19 counties, 149 veins, 255 farms.

The total number of veins is less than the total of the numbers given for the several counties since some of the veins extend into adjoining counties.

Some of the Lewis county zinc deposits may prove workable. The lead veins reported from eastern Estill county are not likely to prove of value, a question which it is hoped may be decided as soon as there may be opportunity to investigate them. Rockcastle county has some barytes deposits which from reports received are encouraging and will be investigated as early as possible. In Casey county, the black barytes which has come to our notice requires investigation. Bracken, Montgomery, Nicholas, Robertson and possibly one or two other counties remain to be investigated.

The following counties have been investigated by the Survey, and either show none of the minerals under consideration or show them in such form and quantity as not to be worthy of prospecting: Barren, Boone, Breckenridge, Carroll, Clinton, Estill (western portion), Gallatin, Grayson, Grant, Marion, Meade, Menefee, Metcalfe, Nelson, Oldham, Pendleton, Shelby and Trimble.

RESOURCES OF LEWIS AND ROWAN COUNTIES.

By F. Julius Fohs.

The greater part of July and August, 1909, was spent in field work in Lewis and Rowan counties. They constitute a rough, hilly country, lying between the good farm lands of Mason, Bath and Felming counties on the west, and the coal lands of Greenup, Carter and Elliott counties on the east. The resources of Rowan and Lewis counties comprise building stones, clays and marls, oil and gas, some zinc ore, and a prolific water supply.

Building stone is one of the chief assets of these counties. The Cuyahoga member of the Waverly formation has an aggregate of 10 to 15 feet of valuable layers of blue to gray freestone of 8 to 32 inches each, suitable for masonry of all kinds. The stone splits, dresses and saws beautifully. In Rowan county, three quarries and plants prepare this stone for market. No modern plants have been erected in Lewis county, and while much stone has been quarried for rough masonry and flagging, the industry has come to a standstill owing to the large use of concrete instead. In the vicinity of Quincy and Garrison there is much good stone near a railroad and a suitable plant could no doubt establish a paying industry. To the south, away from the railroad, the ridges carry much good stone.

The Mississippian limestone, which rests on the Waverly, is suitable for ballast and flux, and is quarried for these purposes in the counties adjoining. A brown marble suitable for interior decoration occurs near the base of this limestone. Just above this a lithographic stone occurs in western Rowan county, but it is flawed too much to be of value. The limestone beneath the Ohio Shale in Lewis county was once manufactured into hydraulic cement, but the plant was not a success. Large quantities of this stone exist suitably located for the building up of an industry, and cheap coal can be had from the adjoining counties. The stone is of good quality and capital together with proper management could no doubt make it a success.

The only workable coal is in Rowan, where it adjoins Elliott county.

Clays, shales and marls of good quality and in large quantity abound in these counties. One brick plant has been built in each county, manufacturing high grade firebrick and building brick. The fire clay used comes from the Conglomerate formation and forms a bed up to 6 feet or more thick. One of these plants is at Firebrick in northeastern Lewis county. The building brick there is made from residual silicious clay and a Waverly shale. The other plant is at Haldeman in eastern Rowan county. The mining of the fireclay in eastern Lewis county was quite an industry until railroads were opened in Carter county when the industry was transferred there. Large quantities of good fireclay occur in these counties still, awaiting development. In eastern Lewis county, three miles east of Concord, one-half mile south of the railroad, is a bed of good fireclay 14 feet thick at the top of the Silurian shales. Beneath this fireclay is more than 100 feet of shales suitable for building and common brick, tile, paints, etc. Some of the beds of the Ohio Shale might be used similarly. Marl beds suitable for fertilizers occur in the Upper Cincinnatian in eastern Lewis county. A red ochre occurs locally in the Conglomerate formation which was quarried for paint at one time.

Much prospecting for oil and gas has been done, covering the greater part of both counties. The only wells being pumped, however, are those of the Alfrey farm, 35 in number,

pumping from the Ragland sand at an average depth of 330 feet, in southwestern Rowan county. In notheastern Rowan county is a gas well which has been burning for seven years. On Straight fork, in Lewis county, some wells at a depth of 100 feet showed minute quantities of petroleum. The Ohio and Sunbury carbonaceous shales are reserves for future distillation of petroleum.

Salt wells were once operative in Salt Lick valley in Lewis county, but are now of only historical interest. Both counties, especially Lewis, are favored with an abundance of good spring waters. Magnesia waters issue in copious springs from the base of the Devonian limestone; the Silurian limestone also yields magnesian waters. Chalybeate and sulphur waters issue from the Ohio shales. Two health resorts are established on the basis of these excellent magnesia, chalybeate and sulphur waters at Esculapia and Glenn Springs in Lewis county. Freestone waters issue from the Waverly formation. Excellent fresh water issues from the Mississippian limestones. In addition, the Ohio river borders Lewis county, the Licking river borders Rowan county and both counties have innumerable creeks.

Zinc occurs in Lewis county in the Devonian limestone. It cements brecciated magnesia limestone. A great number of outcrops were examined but only looked promising enough to suggest future development; this is known as the Capt. Kinney prospect, 4 miles southwest of Vanceburg.

There is an abundant supply of road materials. The roads with a few exceptions are among the worst in the State, largely following creek beds. Nothing could add more to the upbuilding of these counties than the building of good roads. The Cincinnatian limestone of northern and eastern Lewis county, the Mississippian limestones, the hard iron-seamed sandstones (thrown away at the quarries now) of the Waverly formation, and the gravels of the stream beds, yield suitable available materials in all parts of the two counties.

Pyrite and sulphur occur in the Devonian shales, but are not of value. A good bed of molding sand occurs at Sand branch, three miles up the river from Vanceburg.

ANALYSES AND HEAT VALUES OF COALS

By R. D. Quickel.

Prof. Charles J. Norwood, Director,
State Geological Survey.

Sir:

I have the honor to submit herewith a report on the analyses and determinations of heat values (b. t. u's.) made of a number of samples of coal collected by the Survey together with samples sent to the Survey for testing, from time to time. The analyses (compiled from the Survey records) were in the main made by Dr. Alfred M. Peter and Mr. J. S. McHargue, chemists of the Survey. The b. t. u. determinations were made by Mr. George F. Brockman and myself. B. t. u. determinations were made by the Parr calorimeter and by the Emerson bomb calorimeter.

Respectfully,
Ralph D. Quickel.

Analyses Arranged by Counties.

Bell County.

No. 2748. Coal, from mine No. 2, Straight Creek Coal Co., Bell Co., Ky., collected by J. S. Cheyney, 1907, composite of three samples of the Pineville seam.

No. 2749. Coal, from Big Hill Coal Co's. mine, Bell Co., Ky., collected by J. S. Cheyney, 1907. Pineville Seam. Thickness of bed 43 inches coal.

No. 2759. Coal, from Straight Creek Coal Co's. property, Bell C.o, Ky., collected by J. S. Cheyney, 1907, from vein about 200 feet above the Pineville Seam.

No. 2791. Coal, from the Wallsend Coal Co's. Mine No. 1, Bell Co., Ky., collected by A. G. Spillman, December 9, 1906, from No. 1 Pineville Seam.

No. 2792. Coal, from the Wallsend Coal Co's. Mine No. 3, Bell Co., Ky., collected by A. G. Spillman. Composite of two samples from the Pineville Seam.

No. 2793. Coal, from Straight Creek Coal Co's. Mine No. 2, Bell Co., Ky., collected by A. G. Spillman, December 4, 1904. Composite of two samples from the Pineville Seam.

No. 2887. Coal, from Winona Coal & Coke Co's. mine at Gravity, Bell Co., Ky., collected by the Company August 8, 1908, from the Bennets Fork Seam of coal in the Middlesboro District.

No. 2888. Same as No. 2887.

No. 2916. Cannel Coal from the Poplar Lick vein on Hignite Creek. Collected by J. W. Gunn, 1908, on the land belonging to the Middlesboro Land Owning and Leasing Co.

Composition of these Bell County Coals, Air Dried.

Number	2748	2749	2750	2791	2792
Moisture	2.30	2.47	2.26	1.15	1.13
Volatile combustible matter	37.69	39.03	39.68	36.80	35.54
Fixed carbon	56.85	57.16	51.64	60.02	61.22
Ash	3.16	1.34	6.42	2.03	2.11
Total	100.00	100.00	100.00	100.00	100.00
Phosphorus	0.031	0.013	0.009	0.000	0.000
Sulphur	0.89	0.77	3.22	0.65	0.71
Coke	60.01	58.50	58.06	62.05	63.33
Specific gravity	1.265	1.256	1.32	1.27	1.30
Color of ash	Light Brown	Light Brown	Lilac	Reddish Brown	Reddish Brown
Character of coke	Spongy	Spongy	Spongy	Dense	Dense
B. T. U. per lb.	*14,641	*14,952	*14,173	*14,329	*14,173

*By Parr Calorimeter.

Number	2793	2887	2838	2916
Moisture	1.45	1.29	1.27	1.20
Volatile combustible matter	35.50	39.03	37.93	38.75
Fixed carbon	60.74	54.97	56.27	34.43
Ash	2.31	4.71	4.53	25.62
Total	100.00	100.00	100.00	100.00
Phosphorus	0.000	0.003	0.003	0.000
Sulphur	0.91	1.20	1.25	0.54
Coke	63.05	.....	.....	.....
Specific gravity	1.26	1.267	1.247	1.362

	Reddish			Brownish
Color of ash	Brown	Gray	Gray	Gray
Character of coke	Spongy	Spongy	Spongy	Dense
B. T. U. per lb	*14,141	*13,851	*13,726	*10,695

* By Parr Calorimeter.

Boyd County Coal.

No. 3026. Coal, from the Princess Mine, Big Run Coal Co., Princess, Boyd Co., Ky. Sample sent by the Company.

COMPOSITION OF THIS BOYD COUNTY COAL, AIR DRIED.

Number	3026
Moisture	3.30
Volatile combustible matter	34.80
Fixed carbon	53.22
Ash	8.68
Total	100.00
Phosphorus	0.00
Sulphur	2.10
Specific gravity	1.317
B. T. U. per lb.	*12,234

* By Parr Calorimeter.

Crittenden County Coal.

No. 3042. Coal, two miles from Blackford, Crittenden Co., Ky. Collected by John C. Worsham and designated as No. 1. Bed 36 inches.

No. 3043. Same as No. 3042 but designated as No. 2.

COMPOSITION OF THESE CRITTENDEN COUNTY COALS, AIR DRIED.

Number	3042	3043
Moisture	2.07	2.23
Volatile combustible matter	31.65	31.87
Fixed carbon	60.58	60.78
Ash	5.70	5.12
Total	100.00	100.00

Sulphur	1.41	1.37
Coke	54.88	55.66
Specific gravity	1.268	1.33
Color of ash	Brown	Brown
Character of coke	Porous	Porous
B. T. U. per lb.	*13,665	*13,140

* By Bomb Calorimeter.

Daviess County Coal.

No. 2870. Coal, from Owensboro Coal and Land Co's. mine, three miles west of Owensboro in Bon Harbor Hills, Daviess Co., Ky. Collected by F. J. Fohs, June 3, 1908. Thickness of bed 49 inches.

COMPOSITION OF THIS DAVIESS COUNTY COAL.

Number	2870
Moisture	7.89
Volatile combustible matter	33.72
Fixed carbon	44.68
Ash	13.71
Total	100.00
Phosphorus	0.00
Sulphur	4.02
Coke	58.39
Specific gravity	1.372
Color of ash	Lilac
Character of coke	.....
B. T. U. per lb.	*11,735

* By Parr Calorimeter.

Floyd County Coals.

No. 2893. Coal, from Preston Coal Co., Floyd Co., Ky. Collected by A. G. Spillman. No. 1 coal. Section is, coal 6 inches, slate 2 inches. Coal 35 inches, face of main entry.

No. 2894. Coal, from Preston Coal Co., Floyd Co., Ky. Collected by A. G. Spillman, from face of first right. No. 1 coal. Section is, coal 6 inches, slate 2 inches. Coal 37 inches.

COMPOSITION OF THESE FLOYD COUNTY COALS, AIR DRIED.

	2893	2894
Number	2893	2894
Moisture	2.48	2.58
Volatile combustible matter	36.71	37.15
Fixed carbon	52.36	50.87
Ash	8.45	9.40
Total	100.00	100.00
Phosphorus	0.0047	0.0026
Sulphur	1.568	0.92
Specific gravity	1.3234	1.3023
Color of ash	Lilac	Lilac
Character of coke	firm and porous	firm and porous
B. T. U. per lb.	*13,090	*12,870

* By Parr Calorimeter.

Harlan County Coal.

No. 2696. Coal, from mouth of Straight Creek, Poor Fork. Collected by J. M. Hodge, 1906.

COMPOSITION OF THIS HARLAN COUNTY COAL, AIR DRIED.

Number	2696
Moisture	5.92
Volatile combustible matter	32.95
Fixed carbon	56.66
Ash	4.47
Total	100.00
Phosphorus	0.004
Sulphur	0.68
Coke	61.13
Specific gravity	1.378
Color of ash	Reddish yellow
Character of coke	Friable
B. T. U. per lb.	*12,490

* By Parr Calorimeter.

Henderson County Coals.

No. 2869. Coal, from Pittsburg Coal Co's. mine, Baskett, Henderson Co., Ky. Collected by F. J. Fohs, June 4, 1908. Sample is a composite of averages taken from Reeds room, right North entry and second room, first right South entry. Sulphur partly excluded from sample. All slate excluded. Henderson bed.

No. 2905. Coal, from Keystone mine, Henderson Co., Ky. Sample from main heading 550 feet from shaft. Coal 4 feet 9½ inches thick with three prominent sulphur partings, none 1 inch thick.

No. 3105. Coal, from Utopia mine, Utopia Coal Co., Henderson Co., Ky. Collected by F. J. Fohs, December 6, 1907. Thickness of bed 46 inches. Black slate roof, 46 inches coal with sulphur in irregular bands, fireclay floor.

No. 3106. Coal, from Zion Coal Co's. mine, Henderson Co., Ky. Collected by F. J. Fohs, December 4, 1907. Seam has one very thin sulphur band and is harder at the top than at the bottom.

No. 3107. Coal, from Bluff City mine, John Archbold Coal Co., Henderson Co., Ky. Collected by F. J. Fohs, December 5, 1907. Thickness of bed 48 inches.

No. 3108. Coal, from Basket mine, Pittsburg Coal Co., Baskett, Henderson Co., Ky. Collected by F. J. Fohs, from main South heading. Thickness of bed, 44 inches.

No. 3109. Coal, from Spottsville mine, Green River Coal Co., Spottsville, Henderson Co., Ky. Collected by F. J. Fohs, December 3, 1907. Thickness of bed, 44 inches.

No. 3110. Coal, Smith Mills Coal & Mining Co's. mine, Henderson Co., Ky. Collected by F. J. Fohs, December 5, 1907. Depth to top of coal, 173 feet. Thickness of bed, 82 inches.

COMPOSITION OF THESE HENDERSON COUNTY COALS, AIR DRIED.

	2869	2905	3105	3106
Number	2869	2905	3105	3106
Moisture	7.57	3.08	6.23	6.05
Volatile combustible matter	34.95	35.72	34.67	37.23
Fixed carbon	46.06	45.05	46.93	46.02
Ash	11.42	16.15	12.17	10.70
Total	100.00	100.00	100.00	100.00

Phosphorus	0.00	0.00	trace	trace
Sulphur	2.54	7.76	2.58	3.24
Coke	51.48	.....	59.10	56.72
Specific gravity	1.346	1.315	1.34	1.356
Color of ash	lilac	grayish brown	gray	lilac
Character of coke	.....	.....	dense	dense
B. T. U. per lb.	*11,980	*11,540	†11,860	*11,510
Number	3107	3108	3109	3110
Moisture	5.72	5.83	5.75	7.58
Volatile combustible matter	35.23	35.71	38.10	32.24
Fixed carbon	42.60	48.14	46.95	49.21
Ash	16.45	10.32	9.20	10.97
Total	100.00	100.00	100.00	100.00
Phosphorus	trace	trace	trace	trace
Sulphur	6.34	3.11	2.73	2.16
Coke	59.05	58.46	56.15	60.18
Specific gravity	1.441	1.312	0.322	1.332
Color of ash	lilac	lilac	lilac	gray
Character of coke	dense	dense	dense	.....
B. T. U. per lb.	†10,600	†11,760	†12,220	*11,380

* By Parr Calorimeter.
† By Bomb Calorimeter.

Hopkins County Coals.

No. 2789. Coal, from Oak Hill mine, Hopkins Co., Ky. Collected by A. G. Spillman. Composite of averages from room No. 9, 1st South entry and room No. 14, 1st South entry. Thickness of bed, 60 inches and 32 inches.

No. 3103. Coal, from Crabtree Mine, Hopkins Co., Ky. Collected by A. G. Spillman. Composite of averages from room No. 38, off of 10th East entry. Thickness of bed, 60 inches.

No. 3104. Coal, from Crabtree mine, Hopkins Co., Ky. Collected by A. G. Spillman. Taken in cross-cut between 7th East and 8th East entries. Thickness of bed, 64 inches.

Composition of these Hopkins County Coals, Air Dried.

Number	2789	3103	3104
Moisture	1.74	4.45	5.29
Volatile combustible matter	39.97	37.93	37.06

Fixed carbon	50.13	49.77	48.42
Ash	8.16	7.85	9.23
Total	100.00	100.00	100.00
Phosphorus	0.00	0.00	0.00
Sulphur	2.84	2.89	3.57
Coke	58.29	57.62	57.65
Specific gravity	1.28	1.311	1.319
Color of ash	light purple	lilac	lilac
Character of coke	light spongy	dense	dense
B. T. U. per lb.	*11,821	†12,255	†12,620

* By Parr Calorimeter.
†By Bomb Calorimeter.

Johnson County Coals.

No. 2889. Coal, from White House mine, Johnson Co., Ky. Sample from Big Vein.

No. 2890-a. Coal, from White House mine, Johnson Co., Ky. Sample from Big Vein.

No. 2891-b. Coal, from White House mine, Johnson Co., Ky. Sample from Big Vein.

No. 2895. Coal, from Rittenhouse mine, Tibbals Coal Co., collected by A. G. Spillman from near face of First Right entry. No. 1 Seam Section is coal 26 inches. Bone coal 3 inches, coal 5 inches.

No. 2896. Coal, from Meek mine, Johnson Co., Ky., collected by A. G. Spillman from near face of First Left entry. Section is 26 inches coal.

No. 2897. Cannel coal, from Sandy River Coal Co., Johnson Co., Ky. Collected by A. G. Spillman, in Room No. 6, on Bucher entry. 19 inches cannel coal.

No. 2898. Coal, from Sandy River Coal Co., Johnson Co., Ky. Collected by A. G. Spillman, from Room No. 6, Bucher entry. Bituminous coal, 13 inches thick.

No. 2899. Coal, from Rittenhouse mine, Tibbals Coal Co., collected by A. G. Spillman from near mouth of Second Right entry. No. 1 coal. 38 inches thick.

No. 2900. Coal, from near Meek mine, Johnson Co., Ky.

Collected by A. G. Spillman, Second Right air course. Coal 33 inches.

No. 3096. Coal, from Muddy Branch mine, North East Coal Co., Johnson Co., Ky. Collected by A. G. Spillman, in last break through, between 3d and 4th right seam. 16 inches.

No. 3097. Coal, from Muddy Branch mine, North East Coal Co., Johnson Co., Ky. Collected by A. G. Spillman, from face of 1st Left entry. Seam 47 inches.

COMPOSITION OF THESE JOHNSON COUNTY COALS, AIR DRIED.

Number	2889	2890-a	2891-b	2895	2896
Moisture	2.95	2.50	3.12	2.87	2.82
Volatile combustible matter	37.60	32.57	39.20	38.79	37.45
Fixed carbon	49.55	46.98	49.93	54.33	53.25
Ash	9.90	17.95	7.75	4.01	6.48
Total	100.00	100.00	100.00	100.00	100.00
Phosphorus	trace	trace	trace	trace	trace
Sulphur	0.83	0.74	0.96	0.71	0.95
Coke	.....	.....	.....	.....	.....
Specific gravity	1.312	1.389	1.299	1.285	1.2742
Color of ash	lilac	gray	yellow	brown	brown
Character of coke	spongy	dense	porous	firm & porous	firm & porous
B. T. U. per lb.	*12,635	*11,623	*13,016	*13,443	*13,234

Number	2897	2898	2899	2900	3096	3097
Moisture	1.52	2.17	2.52	2.40	3.06	3.40
Volatile comb. matter	46.08	32.75	36.90	37.43	37.44	36.53
Fixed carbon	42.47	50.23	51.96	54.80	55.21	57.43
Ash	9.93	14.85	8.62	5.37	4.29	2.60
Total	100.00	100.00	100.00	100.00	100.00	100.00
Phosphorus	trace	trace	trace	trace	0.00	0.00
Sulphur	0.79	0.82	0.683	0.66	2.11	0.80
Coke	.....	.....	.....	.....	59.50	60.07
Specific Gravity	1.2681	1.4041	1.3238	1.3024	1.303	1.227
Color of ash	brown	brown	brown	brown	lilac	brown
Character of coke	firm & porous	dense	firm & porous	firm & porous	dense	porous
B. T. U. per lb.	*12,990	*11,865	*12,840	*13,330	*12,655	*13,460

* By Parr Calorimeter.

Knott County Coals.

No. 2735. Coal, from mouth of Dan Fork, Buckhorn Creek, Pardee, Knott Co., Ky. Collected by J. M. Hodge, 1906. Thickness of bed, 74 inches.

No. 2755. Coal, from ½ mile above Henderson on Troublesome creek, Jasper Baker, Knott Co., Ky. Collected by J. M. Hodge, October, 1906. Thickness of bed, 47 inches.

No. 2756. Coal, from Carr Fork at mouth of Little Carr, Knott Co., Ky. Collected by J. M. Hodge, October, 1906. Thickness of bed, 46 inches.

COMPOSITION OF THESE KNOTT COUNTY COALS, AIR DRIED.

Number	2735	2755	2756
Moisture	1.76	1.44	2.92
Volatile combustible matter	41.98	41.67	34.90
Fixed carbon	49.67	52.24	54.36
Ash	6.59	4.65	7.82
Total	100.00	100.00	100.00
Phosphorus	0.013	0.009	0.009
Sulphur	1.83	1.05	0.65
Coke	56.26	56.89	62.18
Specific gravity	1.294	1.264	1.367
Color of ash	reddish yellow	reddish brown	salmon
Character of coke	dense spongy	spongy	friable
B. T. U. per lb.	*13,862	*14,329	*12,616

* By Parr Calorimeter.

Lawrence County Coals.

No. 2660 Coal, from Lick Creek entry on left side going up Lawrence county, Ky. Sample marked Dr. Watson's coal, collected by A. R. Crandall, April 27, 1905.

No. 2997. Coal, from Crystal Block Coal Co., Louisa, Lawrence Co., Ky.

COMPOSITION OF THESE LAWRENCE COUNTY COALS, AIR DRIED.

Number	2660	2997
Moisture	4.80	2.95

Volatile combustible matter	36.84	35.18
Fixed carbon	49.82	55.17
Ash	8.54	6.70
Total	100.00	100.00
Phosphorus	0.00	0.00
Sulphur	0.74	1.01
Coke	58.36	.....
Specific gravity	1.319	1.29
Color of ash	flesh	.....
Character of coke	spongy	.....
B. T. U. per lb.	*12,615	*12,997

* By Parr Calorimeter.

Lee County Coals.

No. 2703. Coal, from ⅜-mile up Stone Coal Branch, Sturgeon Creek, Lee Co., Ky. Collected by J. M. Hodge, 1906. Old opening.

No. 2704. Coal, from ¼-mile up Duck Fork, Sturgeon Creek, Lee Co., Ky. Collected by J. M. Hodge, 1906. Main coal.

No. 2819. Coal, from Sinking Creek, Lee Co., Ky. Collected by A. M. Miller, 1907. Coal No. 1 (1st coal above limestone). Thickness of bed 24 inches.

No. 2820. Coal, from Kentucky River Block Mine, White Ash Coal Co., Lee Co., Ky. Collected by A. M. Miller. Lee Formation. Thickness of bed, 37 inches.

No. 2821. Coal, from White Ash Coal Co. mine on Derrickson creek near mouth, Lee Co., Ky. Collected by A. M. Miller. Lee Formation. Coal No. 2. Thickness of bed, 40 inches.

COMPOSITION OF THESE LEE COUNTY COALS, AIR DRIED.

Number	2703	2704	2819	2820	2821
	Not air dried	Not air dried			
Moisture	4.16	3.53	2.72	2.05	1.90
Volatile combustible matter	38.97	40.51	39.67	40.42	41.20
Fixed carbon	49.24	49.00	48.28	50.98	51.09
Ash	7.63	6.96	9.33	6.55	5.81
Total	100.00	100.00	100.00	100.00	100.00

Phosphorus	0.022	0.004	0.00	0.00	0.00
Sulphur	1.97	2.60	4.78	2.86	2.36
Coke	56.87	55.96	57.61	57.53	56.90
Specific gravity	1.345	1.299	1.34	1.29	1.30
Color of ash	brown	purple	red	brown	brownish red
Character of coke	spongy	spongy	.....	.....	.....
B. T. U. per lb.	*13,958	*13,457	*12,540	*12,855	*13,125

*By Parr Calorimeter.

Letcher County Coals.

No. 2697. Coal, from Franks Branch, Oven Fork, Letcher Co., Ky. Collected by J. M. Hodge.

No. 2698. Coal, from Smith Branch, Oven Fork, Letcher Co., Ky. Collected by J. M. Hodge. Thickness of bed 66 inches.

No. 2736. Coal, from Line Fork, Joe Cornett, Letcher Co., Ky. Collected by J. M. Hodge, August, 1906.

No. 2753. Coal, from Right Fork, Millstone Creek, Melvin Tolliver, Letcher Co., Ky. Collected by J. M. Hodge, September, 1907. Thickness of bed, 71 inches.

No. 2754. Coal, from Millstone Branch, Rockhouse creek, John Lexton, Letcher Co., Ky. Collected by J. M. Hodge, September, 1906.

COMPOSITION OF THESE LETCHER COUNTY COALS, AIR DRIED.

Number	2697	2698	2736	2753	2754
Moisture	2.23	2.93	1.01	1.43	0.39
Volatile combustible matter	35.37	33.54	34.04	37.00	46.11
Fixed carbon	56.21	54.12	39.10	53.35	40.50
Ash	6.19	9.41	25.85	8.22	13.00
Total	100.00	100.00	100.00	100.00	100.00
Phosphorus	0.057	0.051	0.00	0.007	0.00
Sulphur	0.66	0.75	0.54	0.71	2.00
Coke	62.40	63.53	64.95	61.57	53.50
Specific gravity	1.313	1.354	1.493	1.333	1.309
Color of ash	buff dense	yellowish dense	reddish brown	buff	grayish brown
Character of coke	spongy	spongy	friable	spongy	dense
B. T. U. per lb.	*13,700	*13,080	*11,310	*13,895	*13,895

* By Parr Calorimeter.

Leslie County Coals.

No. 2737. Cannel coal, from Laurel Fork, Cutshin creek, A. Cornett, Leslie Co., Ky. Collected by J. M. Hodge, August, 1906. Section is 69 inches cannel coal, 6 inches coal.

No. 2738. Cannel coal, from Laurel Fork, Cutshin creek. A. Cornett, Leslie Co., Ky. Collected by J. M. Hodge, August, 1906. Section is Coal (?), cannel coal 69 inches.

COMPOSITION OF THESE LESLIE COUNTY COALS, AIR DRIED.

Number	2737	2738
Moisture	1.56	1.67
Volatile combustible matter	46.94	38.78
Fixed carbon	45.16	53.91
Ash	6.34	5.64
Total	100.00	100.00
Phosphorus	0.00	0.004
Sulphur	0.72	1.34
Coke	51.50	59.55
Specific gravity	1.225	1.290
Color of ash	buff	lt. brown
Character of coke	dense	dense spongy
B. T. U. per lb.	*14,140	*14,140

* By Parr Calorimeter.

Martin County Coals.

No. 2658. Coal, from head of Middle Fork, Rockcastle creek, near Copperas Gap, Martin Co., Ky. Collected by A. R. Crandall. Sample marked E coal. Thickness of bed 62 inches.

No. 2659. Coal, from Pigeon Roost Branch, Laurel Fork of Middle Fork, Rockcastle creek. Collected by A. R. Crandall. April 26, 1905. Sample marked E coal. Thickness of bed, 66 inches.

COMPOSITION OF THESE MARTIN COUNTY COALS, AIR DRIED.

Number	2658	2659
Moisture	3.15	3.05

Volatile combustible matter	38.64	36.83
Fixed carbon	51.25	46.57
Ash	6.96	13.55
Total	100.00	100.00
Phosphorus	0.00	0.00
Sulphur	0.82	0.69
Coke	68.21	60.12
Specific gravity	1.372	1.318
Color of ash	purplish	flesh
Character of coke	spongy	spongy
B. T. U. per lb.	*12,175	*12,210

* By Parr Calorimeter.

McLean County Coals.

No. 2901. Coal, from Green River Coal & Coke Co., Island, McLean Co., Ky. Collected by A. G. Spillman, from face of Room No. 1 on 1st North Entry, East side of shaft. Thickness of bed, 46 inches.

No. 2902. Coal, from Green River Coal & Coke Co., Island, McLean Co., Ky. Collected by A. G. Spillman from face of Room No. 1 on 3d North Entry, East side of shaft. Thickness of bed, 46 inches.

No. 2903. Coal, from Alva Karnes mine, near Island, McLean Co., Ky. Collected by A. G. Spillman, from face of Main East Entry.

No. 2904. Coal, from Alva Karnes mine, near Island, McLean Co., Ky. Collected by A. G. Spillman, from face of Room No. 1 on 2d west Entry. Thickness of bed, 46 inches.

COMPOSITION OF THESE MCLEAN COUNTY COALS, AIR DRIED.

Number	2901	2902	2903	2904
Moisture	2.87	2.68	2.55	2.54
Volatile combustible matter	39.53	37.35	41.18	42.01
Fixed carbon	49.17	47.87	47.14	46.78
Ash	8.43	12.10	9.13	8.67
Total	100.00	100.00	100.00	100.00
Phosphorus	0.00	0.00	0.00	0.00
Sulphur	3.54	2.86	3.30	3.14

Coke	57.60	59.97	56.27	55.45
Specific gravity	1.283	1.344	1.275	1.293
Color of ash	gray	brown	brown	brownish gray
Character of coke	light	.....	.....	.....
B. T. U. per lb.	*12,156	*12,639	*11,970	*12,390

* By Parr Calorimeter.

Menefee County Coal.

No. 2825. Coal, from Red River Valley R. R. mine on Amet Fork of Indian creek, Menefee Co., Ky. Collected by A. M. Miller, 1907. Coal No. 1. Thickness of bed, 31 inches.

COMPOSITION OF THESE MENEFEE COUNTY COALS, AIR DRIED.

Number	2825
Moisture	2.95
Volatile combustible matter	43.28
Fixed carbon	47.93
Ash	5.84
Total	100.00
Phosphorus	0.00
Sulphur	1.52
Coke	53.77
Specific gravity	1.28
Color of ash	gray
Character of coke	.....
B. T. U. per lb.	*12,870

* By Parr Calorimeter.

Morgan County Coals.

No. 3062. Coal, from the North Fork Cannel Coal Co., Wrigley, Morgan Co., Ky. Sample sent by the company and designated as No. 1. Bed, 30 inches.

No. 3063. Coal, from the North Fork Cannel Coal Co., Wrigley, Morgan Co., Ky. Sample sent by the company and designated as No. 2. Bed, 30 inches.

No. 3064. Coal, from the North Fork Cannel Coal Co., Wrigley, Morgan Co., Ky. Sample sent by the company and designated as No. 3. Bed, 30 inches.

No. 3065. Coal, from the North Fork Cannel Coal Co., Wrigley, Morgan Co., Ky. Sample sent by the company and designated as No. 4. Bed, 30 inches.

No. 3066. Coal, from the North Fork Cannel Coal Co., Wrigley, Morgan Co., Ky. An average of samples Nos. 3062 and 3063.

No. 3067. Coal, from the North Fork Cannel Coal Co., Wrigley Morgan Co., Ky. An average of samples Nos. 3064 and 3065.

No. 3074. Cannel coal, from H. M. Collins mine on "May Oakley Branch" of North Fork of Licking river. Sample collected by North Fork Cannel Coal Co., May, 1909.

No. 3164. Coal, from Lee Coal Co's. mine No. 1 at Redwine, about 3 miles from Wrigley, Morgan Co., Ky. Sample collected by the company September, 1909. The company designated this sample as No. 1, representing 14 inches and is known as top coal. Bed, 42 inches.

No. 3165. Coal, from Lee Coal Co's. mine No. 1 at Redwine, about 3 miles from Wrigley, Morgan Co., Ky. Sample collected by the company September, 1909. The company designated this sample as No. 1, representing the bottom coal from top to bottom. Bed, 42 inches.

No. 3166. Coal, from Lee Coal Co's. mine, No. 1 at Redwine about 3 miles from Wrigley, Morgan Co., Ky. Sample collected by the company, September, 1909. The company designates this sample as No. 3, representing the entire bed from top to bottom.

COMPOSITION OF THESE MORGAN COUNTY COALS, AIR DRIED.

Number	3062	3063	3064	3065	3066
Moisture	1.33	1.03	1.30	1.10	1.18
Volatile combustible matter	52.72	42.12	53.25	44.48	47.32
Fixed carbon	32.66	27.85	33.50	30.62	29.41
Ash	13.29	29.00	11.95	23.80	22.22
Total	100.00	100.00	100.00	100.00	100.00
Phosphorus	0.00	0.00	0.00	0.00	0.00
Sulphur	1.57	2.74	1.68	1.28	2.71
Coke	29.37	.....	.....	.....	.....
Specific gravity	1.227	1.417	1.248	1.361	1.310
Color of ash	lilac	lilac	lilac	lilac	lilac

Character of coke	dense	dense	dense	dense	dense
B. T. U. per lb.	*12,530	*11,289	*13,060	*11,283	*11,285
Number	3067	3074	3164	3165	3166
Moisture	1.38	1.60	1.45	1.65	1.38
Volatile combustible matter	47.17	49.68	45.25	51.80	50.19
Fixed carbon	33.68	31.72	28.50	33.25	32.21
Ash	17.77	17.00	24.80	13.30	16.22
Total	100.00	100.00	100.00	100.00	100.00
Phosphorus	0.00	0.00	0.00	0.00	0.00
Sulphur	1.71	1.88	1.57	1.78	1.46
Coke	.....	.....	53.30	46.55	48.43
Specific gravity	1.314	1.294	1.406	1.283	1.308
Color of ash	lilac	brown	brown	brown	brown
Character of coke	dense	very friable	.....	porous	.....
B. T. U. per lb.	*11,940	*11,140	*12,045	*13,160	*12,605

* By Parr Calorimeter.

Muhlenberg County Coals.

No. 3070. Coal, from W. P. Robertson's shaft at Moorman, Muhlenberg Co., Ky. Collected by J. M. Thompson, May 3, 1909. Bed, 60 inches.

No. 3075. Coal, from Diamond Block Mines, near Drakesboro, Muhlenberg Co., Ky. Collected by J. M. Thompson, May, 1909.

COMPOSITION OF THESE MUHLENBERG COUNTY COALS, AIR DRIED.

Number	3070	3075
Moisture	6.47	5.03
Volatile combustible matter	34.98	36.52
Fixed carbon	50.45	41.33
Ash	8.10	17.12
Total	100.00	100.00
Phosphorus	0.00	0.00
Sulphur	2.51	2.90
Coke	42.35	58.45
Specific gravity	1.333	1.357
Color of ash	lilac	lilac
Character of coke	porous	dense
B. T. U. per lb.	*11,969	*10,880

* By Parr Calorimeter.

Owsley County Coals.

No. 2818. Coal, from D. H. Reynolds bank, 1 mile from Booneville, on Gabbard Fork, Owsley Co., Ky. Collected by A. M. Miller, 1907. Breathitt Formation. Thickness of bed, 28 inches.

COMPOSITION OF THIS OWSLEY COUNTY COAL, AIR DRIED.

Number	2818
Moisture	2.02
Volatile combustible matter	36.82
Fixed carbon	53.68
Ash	7.48
Total	100.00
Phosphorus	0.00
Sulphur	1.09
Coke	61.16
Specific gravity	1.284
Color of ash	brown
Character of coke	dense
B. T. U. per lb.	*13,415

* By Parr Calorimeter.

Perry County Coals.

No. 2732. Coal, from Lost creek, J. E. Campbell, Perry Co., Ky. Collected by J. M. Hodge. August, 1906. Thickness of bed, 58 inches.

No. 2733. Coal, from 15 mile Branch, Lost creek, Perry Co., Ky. Collected by J. M. Hodge, August, 1906. Thickness of bed, 88 inches.

No. 2734. Coal, from Old House Branch below Cutshin creek, Henry Begley, Perry Co., Ky. Collected by J. M. Hodge, August, 1906. Thickness of coal, 72 inches.

COMPOSITION OF THESE PERRY COUNTY COALS, AIR DRIED.

Number	2732	2733	2734
Moisture	2.09	2.48	1.91
Volatile combustible matter	38.61	35.51	38.29
Fixed carbon	54.21	52.43	52.45
Ash	5.09	9.53	7.35
Total	100.00	100.00	100.00

Phosphorus	0.007	0.033	0.023
Sulphur	0.83	1.05	0.73
Coke	——	62.01	59.80
Specific gravity	1.297	1.337	1.297
Color of ash	lt. buff	yellowish gray	lt. buff
Character of coke	dense spongy	dense spongy	dense spongy
B. T. U. per lb.	*14,018	*12,958	*13,613

* By Parr Calorimeter.

Pike County Coals.

No. 3083. Coal, from Greenough Coal & Coke Co., Hellier, Pike Co., Ky. Collected from Upper Elkhorn seam by A. G. Spillman. Section equal 45 in.

No. 3085. Coal, Edgewater Coal & Coke Co., Hellier, Pike Co., Ky. Collected near face of main entry Lower Elkhorn seam, by A. G. Spillman. Section is, laminated coal 17 inches, coal 15 inches.

No. 3086. Coal, from Henry Clay Mine, Lookout, Pike Co., Ky. Collected from face of room No. 6 on 2d Left, Lower Elkhorn seam, by A. G. Spillman.

No. 3088. Coal, from Pike County Coal & Coke Co's. mine, Hellier, Pike Co., Ky. Collected from face of 1st right entry by A. G. Spillman. Section is, coal 45 inches.

No. 3089. Coal, from Greenough Coal & Coke Co's. mine, Hellier, Pike Co., Ky. Collected by A. G. Spillman, from near face of main entry, Upper Elkhorn seam. Section is 46 inches coal.

No. 3090. Coal, from Henry Clay mine, Lookout, Pike Co., Ky. Collected by A. G. Sillman, from face of main entry, Upper Elkhorn seam. Section is 36 inches coal.

No. 3094. Coal, from Greenough Coal & Coke mine, Hellier, Pike Co., Ky. Collected by A. G. Spillman, from 3d left air course, Upper Elkhorn seam. Section is 46 inches coal.

No. 3095. Coal, from Pike County Coal & Coke Co's. mine, Hellier, Pike Co., Ky. Collected by A. G. Spillman, from 3d left air course, Lower Elkhorn seam. Section is, coal 29 inches, laminated coal 24 inches.

COMPOSITION OF THESE PIKE COUNTY COALS, AIR DRIED.

Number	3083	3085	3086	3088
Moisture	1.70	1.67	1.75	1.70
Volatile combustible matter	33.00	32.43	33.00	35.50
Fixed carbon	60.05	64.10	62.25	61.75
Ash	5.25	1.80	3.00	1.05
Total	100.00	100.00	100.00	100.00
Phosphorus	trace	trace	trace	trace
Sulphur	0.62	0.50	0.69	0.61
Coke	65.30	65.90	65.25	62.80
Specific gravity	1.280	1.260	1.289	1.270
Color of ash	brown	brownish	brown	brown
Character of coke	porous	porous	porous	porous
B. T. U. per lb.	†13,540	†14,835	†14,185	†14,715
Number	3089	3090	3094	3095
Moisture	1.50	1.55	1.60	1.70
Volatile combustible matter	35.65	35.60	32.80	31.39
Fixed carbon	61.80	60.20	60.78	62.69
Ash	1.05	2.65	4.82	4.22
Total	100.00	100.00	100.00	100.00
Phosphorus	trace	trace	trace	trace
Sulphur	0.64	0.65	0.62	0.44
Coke	62.85	62.85	65.60	66.91
Specific gravity	1.267	1.283	1.293	1.316
Color of ash	brown	brown	brown	brown
Character of coke	porous	porous	dense	porous
B. T. U. per lb.	†14,755	†14,445	*13,570	*14,005

* By Parr Calorimeter.
† By Bomb Calorimeter.

Powell County Coals.

No. 2822. Coal, from about 1 mile from Dundee, Clear Branch, Powell Co., Ky. Collected by A. M. Miller, 1907. Sample is Coal No. 1. (Lowest coal above limestone.) Thickness of bed, 17 inches to 24 inches.

COMPOSITON OF THIS POWELL COUNTY COAL, AIR DRIED.

Number	2822
Moisture	2.96

Volatile combustible matter	37.63
Fixed carbon	43.85
Ash	15.56
Total	100.00
Phosphorus	0.00
Sulphur	4.55
Coke	59.41
Specific gravity	1.32
Color of ash	reddish
Character of coke	——
B. T. U. per lb	*10,984

* By Parr Calorimeter.

Union County Coals.

No. 3069. Coal, from Kentucky Coal Mining Co's. mine No. 2, at Waverly, Union Co., Ky. No. 11 coal.

No. 3068. Coal, from Kentucky Coal Mining Co's. mine No. 1, at Waverly, Union Co., Ky. No. 11 coal.

No. 3159. Coal, from River and Rail Coal & Coke Co., Uniontown, Union Co., Ky. Collected by company.

COMPOSITION OF THESE UNION COUNTY COALS, AIR DRIED.

Number	3069	3068	3159
Moisture	3.73	3.30	7.20
Volatile combustible matter	39.79	39.60	39.90
Fixed carbon	46.23	41.58	46.00
Ash	10.12	15.52	6.90
Total	100.00	100.00	100.00
Phosphorus	0.00	0.00	0.00
Sulphur	3.89	4.69	3.18
Coke	36.24	26.06	52.90
Specific gravity	1.351	1.366	1.320
Color of ash	gray	gray	lilac
Character of coke	dense	dense	porous
B. T. U. per lb	*11,720	*10,722	*12,530

* By Parr Calorimeter.

Webster County Coals.

No. 2668. Coal, from Sebree Coal Co., Webster Co., Ky. Sent by Sebree Coal Co.

No. 2788. Coal, from Wheatcroft Mine (shaft), now West Kentucky Coal Co's. Colliery G. Composite of average sample collected by A. G. Spillman, from the head of west entry and from room No. 11 on Main West Entry.

No. 3082. Coal, from Shamrock mine, Providence, Webster Co., Ky. Collected by A. G. Spillman, from near face of 2d West Entry.

No. 3084. Coal, from S. K. Luton's mine, Providence, Webster Co., Ky. Collected by A. G. Spillman, from near face of 1st left entry. Thickness of bed, 55 inches.

No. 3087. Coal, from Shamrock mine, Providence, Webster Co., Ky. Collected by A. G. Spillman, from near face of South entry. The section is coal, 46 inches, clay 2 inches, coal, 24 inches.

No. 3091. Machine dust from electric machine in shaft mine of Providence Coal Co., Providence, Webster Co., Ky. Collected by A. G. Spillman. Sample consisted of chiefly coal dust and very small lumpss of coal.

No. 3092. Coal, from S. K. Luton's mine, Providence, Webster Co., Ky. Sample collected by A. G. Spillman, from near face of Main entry. Thickness of bed, 58 inches.

No. 3102. Coal, from No. 9 seam, Providence, Webster Co., Ky.

COMPOSITION OF THESE WEBSTER COUNTY COALS, AIR DRIED.

Number	2668	2788	3082	3084
Moisture	8.87	1.16	3.70	3.31
Volatile combustible matter	40.62	37.94	40.38	36.29
Fixed carbon	45.52	51.17	49.97	51.03
Ash	4.99	9.73	5.95	9.37
Total	100.00	100.00	100.00	100.00
Phosphorus	0.00	0.00	trace	trace
Sulphur	2.29	3.91	2.72	4.44
Coke	50.51	60.90	55.92	60.40
Specific gravity	1.301	1.42	1.291	1.350
Color of ash	lt. brown	purple	lilac	lilac
Character of coke	spongy	——	porous	porous
B. T. U. per lb	*12,709	*12,708	†12,995	†12,255
Number	3087	3091	3092	3093
Moisture	3.70	3.60	3.15	2.60

Volatile combustible matter	40.45	34.55	38.05	35.15
Fixed carbon	50.98	50.51	49.90	52.15
Ash	4.87	11.34	8.90	10.10
Total	100.00	100.00	100.00	100.00
Phosphorus	trace	trace	trace	0.00
Sulphur	2.77	3.52	3.80	4.13
Coke	55.85	61.85	58.80	62.25
Specific gravity	1.304	1.343	1.331	1.349
Color of ash	lilac	lilac	lilac	lilac
Character of coke	porous	porous	porous	porous
B. T. U. per lb.	†13,365	†12,075	†12,710	†12,770

* By Parr Calorimeter.
† By Bomb Calorimeter.

Whitley County Coals.

No. 2751. Coal, from Anderson Coal Co., Halsey, Whitley Co., Ky.

No. 2796. Coal, from Mount Morgan mine, Jellico coal, Whitley Co., Ky. Composite of averages from face of No. 4 entry, and from room No. 24, on No. 11 entry. Thickness of bed, 34 and 32 inches.

No. 3058. Coal, from the Gatliff Coal Co., Williamsburg, Whitley Co., Ky. Sent by the company, May 10, 1909, and designated as "Top Bench."

No. 3059. Coal, from the Gatliff Coal Co., Williamsburg, Whitley Co., Ky. Sent by the company May 10, 1909. and designated as "Middle Bench."

No. 3060. Coal, from the Gatliff Coal Co., Williamsburg, Whitley Co., Ky. Sent by the company May 10, 1909. and designated as "Bottom Bench."

No. 3061. Coal, from the Gatliff Coal Co., Williamsburg, Whitley Co., Ky. Sent by the company May 10, 1909. and designated as "Top, Middle, and Bottom Benches." The sample is an average of Nos. 3058, 3059 and 3060.

No. 3160. Coal, from the Acme Blue Gem Coal Co., Gatliff, Whitley Co., Ky. Average sample collected by the company, July 1, 1909.

COMPOSITION OF THESE WHITLEY COUNTY COALS, AIR DRIED.

Number	2751	2796	3058	3059
Moisture	1.90	1.18	2.32	2.38
Volatile combustible matter	27.32	37.54	43.27	40.82
Fixed carbon	43.71	58.45	52.27	54.55
Ash	27.07	2.83	2.15	2.25
Total	100.00	100.00	100.00	100.00
Phosphorus	0.02	0.00	trace	trace
Sulphur	0.92	1.23	0.63	0.89
Coke	70.78	61.28	50.12	52.30
Specific gravity	1.557	1.27	1.267	1.263
Color of ash	buff	whitish	brown	brown
Character of coke	dense	lt. spongy	porous	porous
B. T. U. per lb.	*10,825	*14,111	*14,120	*13,652

Number	3060	3061	3160
Moisture	2.35	2.07	2.17
Volatile combustible matter	39.98	41.73	44.13
Fixed carbon	55.72	53.92	49.90
Ash	1.95	2.28	3.80
Total	100.00	100.00	100.00
Phosphorus	trace	0.00	0.00
Sulphur	0.65	0.70	2.94
Coke	53.77	51.64	53.70
Specific gravity	1.275	1.266	1.301
Color of ash	brown	brown	lilac
Character of coke	porous	porous	porous
B. T. U. per lb.	*13,558	*13,527	†14,054

* By Parr Calorimeter.
† By Bomb Calorimeter.

Wolfe County Coals.

No. 2823. Coal, from Henry Alexander's bank near Campton. Collected by A. M. Miller. Thickness of bed 61 inches. Bed has a 6-inch clay parting, 29 inches from base of coal, 3 inches shaly coal and a 3-inch shaly streak, 7½ inches from top.

No. 2824. Coal, from Rem Allen's coal seam near Campton. Collected by A. M. Miller. Thickness of bed, 47 inches. The thickness includes clay partings reducing coal to 34 inches.

COMPOSITION OF THESE WOLFE COUNTY COALS, AIR DRIED.

Number	2823	2824
Moisture	3.30	3.25
Volatile combustible matter	36.65	36.22
Fixed carbon	52.35	47.91
Ash	7.70	12.62
Total	100.00	100.00
Phosphorous	0.00	0.00
Sulphur	2.13	0.91
Coke	60.05	60.53
Specific gravity	1.26	1.26
Color of Ash	gray	yellowish brown
B. T. U. per lb.	*12,542	*12,058

* By Parr Calorimeter.

CO-OPERATION IN MAPPING

BRIEF STATEMENT OF FIELD WORK.

Following is a succinct statement of the field work accomplished, during the calendar years 1908 and 1909, in mapping carried on in co-operation by the U. S. Geological Survey and the Kentucky Geological Survey, as given by Col. R. C. Rizer, Acting Director of the U. S. Geological Survey. The year, under the agreement between the two Surveys, for which allotments are made runs from July 1st to June 30th, but for present purposes it is believed best to present results according to calendar years.

FROM JANUARY 1, TO DECEMBER 31, 1908.

		LEVELS			TRAVERSE		
Quadrangle	Area mapped Sq. Mi.	Primary. Mi.	P.B.M's.	Secondary. Mi.	Prim'y. Mi.	Perm. Mks.	Second'y. Mi.
Princeton	238	78	12	502	....	....	868
Horsebranch	.....	....	....	....	138	22	....
Rochester	.....	....	....	....	....	....	....
Morgantown	.....	...	....	....	....	....	....
	238	78	12	502	138	22	868

Triangulation was carried on in Lewis and Rowan counties and provided partial control for the Vanceburg, Olive Hill, Quincy, and Morehead quadrangles, 8 stations being occupied and 9 permanent marks set. Triangulation for the Kentucky portion of the Williamson quadrangle was completed, and that for the east half of the old Prestonburg was commenced, 3 permanent marks being set.

FROM JANUARY 1, TO DECEMBER 31, 1909.

		LEVELS			TRAVERSE		
Quadrangle	Area mapped Sq. Mi.	Primary. Mi.	P.B.M's.	Secondary. Mi.	Prim'y Mi.	Perm. Mks.	Second'y Mi.
Dawson Spgs.	238	68	12	....	....	....	765
Monticello	20	....	....	....	....	....	69
Paintsville	.....	59	17	....	....	....	....
	258	127	38		....	....	844

Triangulation was continued in Lewis and Rowan and adjoining counties, and completed such control for the Soldier, Ewing, Rectorville, Flemingsburg, and Mt. Sterling quadrangles; also for Inez and Laynesville; 25 stations being occupied and 21 permanent marks set.