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PART II.—COAL AND LIGNITE

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CONTENTS.

ILLUSTRATIONS.

CONTRIBUTIONS TO ECONOMIC GEOLOGY, 1907, PART II.

COAL AND LIGNITE.

MARIUS R. CAMPBELL, *Geologist in Charge.*

INTRODUCTION.

By MARIUS R. CAMPBELL.

GENERAL STATEMENT.

During the year 1907 a greater addition was made to existing knowledge regarding the outline, extent, quality, and tonnage of the western coal fields than had been made in any previous year. This was due largely to the fact that during the latter part of 1906 and the early part of 1907 supposed coal lands to the extent of 67,000,000 acres, or 104,000 square miles, were withdrawn from entry, and the United States Geological Survey was called upon to examine and to classify these lands so that they might be restored to coal entry.

Before this work was done it was impossible to determine with any degree of accuracy the positions of many of the coal fields in the Rocky Mountain region, or to say what were their sizes and shapes and the extent of their coal resources. Now, however, the coal areas are much better known, and a map representing them has been prepared.[a] A copy of this map on a small scale, in black and white, is here given (Pl. I) for the purpose of showing the extent of the coal fields and the areas in which surveys were carried on during the last year.

In preparing this map it was deemed necessary to revise and systematize the nomenclature of the coal areas. Accordingly a committee consisting of George H. Ashley, Joseph A. Taff, and

[a] Map of coal fields of the United States, U. S. Geol. Survey, 1908

Alfred R. Schultz was appointed to consider this question and make recommendations which should govern the practice of the Geological Survey. The report of this committee, in brief, provides for the recognition of four classes of areas, as follows:

1. *Coal province.*—This corresponds in a general way with a geologic or physiographic province. In order from east to west the coal provinces of the United States are the Eastern, Interior, Gulf, Northern Great Plains, Rocky Mountain, and Pacific Coast.

2. *Coal region.*—This term is to be applied to a part of a province which has a uniform geologic history and topographic expression, and which is manifestly too large to be considered as a coal field. In the Eastern coal province the following coal regions are recognized: Atlantic Coast, Anthracite, and Appalachian. In the Interior: Eastern, Northern, Western, and Southwestern. In the Northern Great Plains: Fort Union, Assinniboine, and Black Hills. In the Rocky Mountain: San Juan River, Southwestern Utah, Raton Mountain, Denver, Uinta, Green River, Bighorn Basin, and Judith Basin.

3. *Coal field.*—A coal field is defined as (*a*) an isolated area that is essentially a geologic and topographic unit, or (*b*) an arbitrary part of an extended coal region that for economic or geologic reasons may be considered a unit, separate and apart from the rest of the region. The Southern Anthracite, Cahaba, Bull Mountain, Great Falls, Hanna, Canon City, Cerrillos, Roslyn, and Coos Bay fields are examples of the first class; and the Pittsburg, New River, Pocahontas, and Belleville fields are examples of the second class.

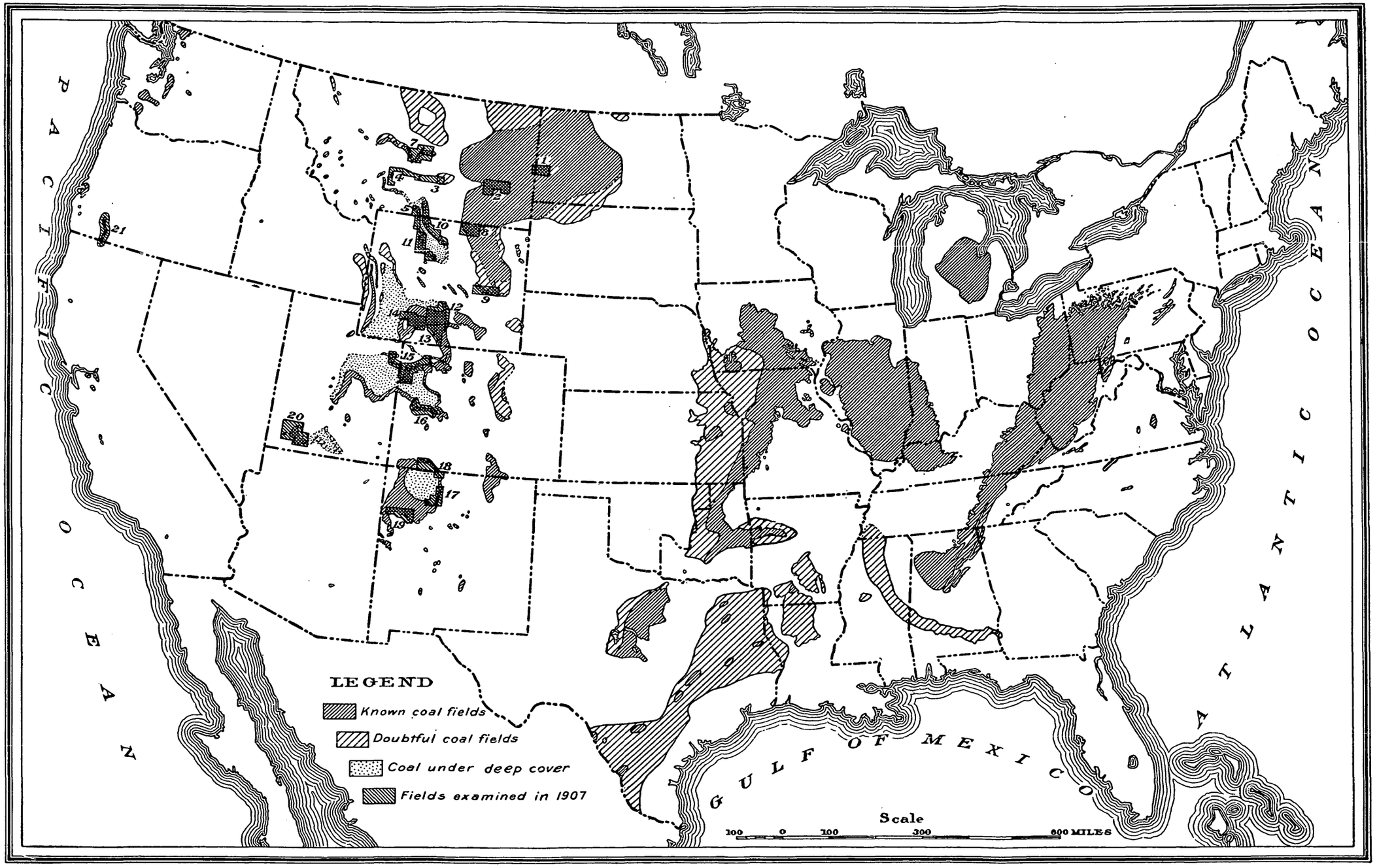
4. *Coal district.*—This is recognized as a subdivision of a field. Its limits are generally controlled by commercial conditions, and it marks a center of development and production.

A novel feature of the new coal map is the attempt to represent many of the great structural basins of the Rocky Mountains as coal bearing, although the coal in the center of the basin is in many places so deeply covered by later barren sediments that it is not available at the present time, and in some basins it is even doubtful if it can ever be mined. The main difference, however, in the outline of the coal fields here shown, as compared with those represented on any previous map, is due to the increased knowledge already referred to, which is more fully presented in the various papers constituting this volume.

GEOLOGIC WORK.

GENERAL OUTLINE.

Early in June, 1907, sixteen geologic parties were outfitted and placed in the field, in the States of North Dakota, Montana, Wyoming, Colorado, Utah, and New Mexico, to classify as much of the land which had previously been withdrawn by departmental orders as time and means would permit. In all about 20,000 square miles were



MAP SHOWING COAL FIELDS OF THE UNITED STATES.

Fields surveyed in 1907: 1, Sentinel Butte, North Dakota-Montana; 2, Miles City, Montana; 3, Bull Mountain, Montana; 4, Crazy Mountains, Montana; 5, Red Lodge, Montana; 7, Lewistown, Montana; 8, Sheridan, Wyoming; 9, Glenrock, Wyoming; 10, Bighorn Basin, northeast side, Wyoming; 11, Bighorn Basin, southwest side, Wyoming; 12, Great Divide Basin, Wyoming; 13, Little Snake River, Wyoming; 14, Rock Springs, Wyoming; 15, Uinta Basin and Henrys Fork, Colorado-Utah; 16, Grand Mesa, Colorado; 17, San Juan River basin, southeastern part, New Mexico; 18, Durango, Colorado-New Mexico; 19, San Juan River basin, southern part, New Mexico; 20, Harmony, Colob, and Kanab, Utah; 21, Rogue River Valley, Oregon.

examined and classified. The work was done with two purposes in view, namely, (1) to classify the land for the purpose of restoring it to coal entry, and (2) to obtain information regarding the accessibility of the fields, quality of coal, correlation of coal beds, and in fact all data of a geologic and economic character.

It is proposed to publish detailed reports of the work of each party containing the information thus accumulated; but inasmuch as many of these reports could not be written until the completion of the work it has been thought best to prepare a preliminary statement containing a brief account of the investigation made by each party during the year. These papers, which make up the present volume, give only the more important and obvious facts for immediate use. Similar reports were published in Bulletin 316, descriptive of fields examined during the year 1906–7, and in Bulletin 285, relative to fields examined in the year 1905–6. The maps accompanying this volume are necessarily on a small scale and incomplete, but the full reports on each field will contain contour maps in colors, on a uniform scale of 1 to 125,000.

The field work on which these reports are based consisted of tracing and mapping outcrops of the various geologic formations and coal beds according to land surveys, care being taken to tie such meanders to stones and other monuments marking the section corners; of examining the coal beds wherever possible, to determine the thickness and character of the coal; and of taking samples for chemical analysis.

WESTERN FIELDS.

In some of the Western States the geologic parties were so situated that it was impossible to provide for field supervision except by the writer; hence in a large measure their work was carried on independently of other parties.

In central Montana and northern Wyoming the work of five parties was so closely related that they were placed under the direct supervision of Cassius A. Fisher, and similarly four parties in southern Wyoming were placed under the control of A. C. Veatch. Unfortunately during the field season Mr. Veatch was detailed to other work, and the parties previously under his direction carried on their work independently of those in adjacent regions. The work done by the various parties is briefly summarized as follows:

North Dakota.—A party under the joint direction of A. G. Leonard, State geologist, and Carl D. Smith, of the Federal Survey, made an examination of the Sentinel Butte lignite field of western North Dakota. As shown by area No. 1 on Pl. I, work was begun at Medora and carried westward along the Northern Pacific Railway into Montana. Professor Leonard remained with the party only while it was in North Dakota, and after that it was in charge of Mr. Smith. It

was the intention to extend the survey to Glendive, on Yellowstone River, but Mr. Smith was needed to complete work at Miles City, Mont., and consequently the territory examined extended only from Medora to Wibaux, Mont., a little west of the North Dakota line.

Montana.—In Montana six geologic parties were engaged in the study of coal fields during the summer of 1907, as follows:

1. A party under the direction of Arthur J. Collier made a survey of the coal and lignite field in the vicinity of Miles City, on Yellowstone River, as shown by area No. 2 on Pl. I. In the middle of the field season Mr. Collier was called away to other work, and the survey was completed by the union of Mr. Collier's and Mr. Smith's parties under the latter's direction.

2. A party under the supervision of Lester H. Woolsey made a survey of what was supposed to be a coal field along Musselshell River from Shawmut eastward. No coal of workable thickness was found in this region, and late in the season work was begun on the Bull Mountain coal field near Roundup, as shown by area No. 3, Pl. I. This is a promising field, and is likely to be developed in the near future to supply coal to the new line of the Chicago, Milwaukee and St. Paul Railway.

3. A party under the direction of Chester W. Washburne examined the Bridger field of Carbon County, south of Yellowstone River. This is an important field, but the coal of workable thickness does not extend far in either direction. As shown by area No. 10 on Pl. I, Mr. Washburne's field is largely in Wyoming, and consequently his paper is given under that State.

4. Elmer G. Woodruff's party made a detailed survey of the Red Lodge coal field, which includes the recent extensive developments on Bear Creek. This is one of the great coal fields of the State, not so much on account of its area as on account of the number and thickness of the coal beds and the quality of the coal. The field examined by Mr. Woodruff is represented by area No. 5, Pl. I.

5. A party directed by Ralph W. Stone mapped and studied a supposed coal field along Musselshell River from the west line of the field examined by Mr. Woolsey to the head of the stream, and from the divide westward and southward along the Montana Railroad. This field is represented by area No. 4 on Pl. I. Mr. Stone succeeded in showing that this region does not contain workable coal, and consequently can not be counted as a source of supply for the future.

6. A party under the direction of William R. Calvert examined and mapped the Lewistown coal field from a point 20 miles east of Lewistown to the east end of the Little Belt Mountains, where connection was made with the Great Falls field surveyed by Mr. Fisher in 1906. The field examined by Mr. Calvert is represented by area No. 7 on Pl. I.

Wyoming.—In Wyoming seven parties were engaged in studying and mapping the coal fields, which, if area and tonnage are considered, are probably more extensive than the fields of any other State. The fields examined by the various parties are as follows:

1. A party under the direction of Elmer G. Woodruff made an examination of the southwest side of the Bighorn Basin from the Montana line through Cody and Meeteetse nearly to Thermopolis, on Bighorn River, as shown by area No. 11 on Pl. I. For a long time these fields have been practically inaccessible on account of lack of railroad facilities, but recently a branch of the Chicago, Burlington and Quincy Railway has been built up Bighorn River to the south end of the basin, and the country is being rapidly developed.

2. Chester W. Washburne with a party of geologists made an examination of the northeast side of the Bighorn Basin, from the Montana line to a point south of Basin, as shown by area No. 10 on Pl. I. The coal on this side of the basin is not so promising as that described by Mr. Woodruff, but there are a few fields where coal mining doubtless will be carried on, at least to supply the local demand.

3. A party under the direction of Joseph A. Taff studied and mapped a coal field in the vicinity of Sheridan. This field includes the mines at Dietz, Carneyville, and Monarch, and probably equally productive territory to the north and east. The area mapped by Mr. Taff is represented by No. 8 on Pl. I. This field is part of the great Fort Union coal region, which includes a large part of northeastern Wyoming, eastern Montana, and western North Dakota.

4. A party under the leadership of E. Wesley Shaw examined and mapped the extreme south end of the Fort Union coal region near Douglas, on North Platte River. This is known as the Glenrock coal field, and is represented by area No. 9 on Pl. I. Mr. Shaw's report seems to show that the coal beds of the southern point of the Fort Union region are of little value away from the present centers of production at Glenrock and Big Muddy.

5. A party under the direction of Max W. Ball made an examination of the Little Snake River coal field, which lies south of the Union Pacific Railroad and west of the Encampment mining region, and which is represented by area No. 13 on Pl. I. The examination of this field was incomplete, Mr. Ball not having time to extend his work to the eastern margin of the coal field, nor to the Yampa coal field on the south, surveyed by Messrs. Fenneman and Gale in 1905.

6. A party under E. E. Smith examined the northern part of the great coal region along the Union Pacific Railroad, from the railroad northward to the mountain rim which marks the limit of the field. This field occupies almost the entire area of the Great Divide Basin, which, although situated on the Continental Divide, has no outward drainage. The field is represented by area No. 12 on Pl. I.

7. A party under the direction of Alfred R. Schultz made a survey of the coal fields exposed on the north flank of the Rock Springs dome, an uplift near the center of the Green River Basin, which brings to the surface lower and more valuable coal beds than are present in the surrounding region. The field mapped is represented by area No. 14 on Pl. I.

Colorado.—Only three geologic parties were at work during the summer of 1907 in the State of Colorado. The fields examined by them are as follows:

1. A party under the leadership of Hoyt S. Gale continued the mapping of the northern rim of the Uinta Basin from the Danforth Hills to Vernal, Utah, and then made a hurried reconnaissance of the Henrys Fork field, north of Uinta Mountains. The former is the westward extension of fields surveyed by Mr. Gale in 1906 and by Messrs. Fenneman and Gale in 1905. The territory examined is represented by area No. 15 on Pl. I.

2. A party under the direction of Willis T. Lee made an examination of the southern rim of the Uinta Basin from Grand Junction to Somerset. This is generally known as the Grand Mesa field, and is represented as area No. 16 on Pl. I. Generally the coal beds are inaccessible at the present time, but in the vicinity of Somerset a branch line of the Denver and Rio Grande Railroad extends into the coal field and development has begun.

3. A party under the leadership of James H. Gardner examined the Durango coal field from Durango eastward to Lumberton, N. Mex. In 1905 a hurried examination was made by F. C. Schrader[a] of the eastern rim of this basin, but no detailed mapping of the outcrop of the coal-bearing formations was attempted. Accordingly during the last season Mr. Gardner made a resurvey of the outcrops for the purpose of more definitely locating them with reference to public-land corners, and of determining the coal resources of the field. The area surveyed is represented by No. 18 on Pl. I.

New Mexico.—In New Mexico only two coal fields were examined during the summer of 1907. These are located on the margin of the San Juan River basin, as follows:

1. A party under the direction of James H. Gardner resurveyed the southeastern rim of the basin from Gallina to Raton Springs, as indicated by area No. 17, Pl. I. This had previously been examined by Mr. Schrader in 1905, but not with sufficient care to classify the land.

2. Mr. Gardner also mapped the southern rim of the basin from Gallup to San Mateo. (See area No. 19, Pl. I.)

Utah.—In Utah the coal fields are fairly well known, except those in the southern part of the State, which have been attracting so much attention in late years that it seemed advisable to examine them.

[a] Bull. U. S. Geol. Survey No. 285, 1906, pp. 241–258.

A party under the direction of George B. Richardson made a survey of the so-called anthracite field of Iron County, and then extended its work to the east as far as the season would permit. The territory examined is represented by area No. 20 on Pl. I. According to Mr. Richardson's report, this region is rugged and not easily accessible, but as it is near the San Pedro, Los Angeles and Salt Lake Railroad, it seems possible that it may be extensively developed in the near future, and coal from this field may be taken to the Southwest, where there is a great and growing demand for fuel.

Oregon.—The coal fields of Oregon are neither extensive nor promising. Many occurrences of coal have been noted, but either the beds are too thin for practical mining or the coal is too impure for commercial use. J. S. Diller examined a small coal field in Rogue River valley, east of Medford and Ashland, as shown by No. 21, Pl. I, but it can not be regarded as a promising source of fuel. The same may be said of a small field above Heppner, in Morrow County, as described by W. C. Mendenhall in this bulletin.

EASTERN FIELDS.

The present volume does not contain the results of geologic work in the eastern coal fields, as provision has been made for the publication of these results elsewhere. Work of this character was in progress in two States only in 1907, namely, Illinois and Pennsylvania.

Illinois.—Work on the coal fields of Illinois was carried on jointly by the State and Federal surveys, with the understanding that each organization should have access to the results obtained by the field parties of the other. Under this arrangement certain areas have been studied and mapped. Reports of this work will appear in the Yearbook of the State Survey, and consequently are omitted from this bulletin.

Pennsylvania.—In 1907 considerable new work was done in the bituminous coal fields of Pennsylvania under the direction of George H. Ashley. This work was done by the Federal Survey, in cooperation with the State organization. The close detailed work in this State is of the utmost economic importance, but as brief accounts are to appear in a progress publication by the State, they will be omitted here.

Virginia.—No regular geologic work was done in Virginia, but a brief examination of the Black Mountain coal field was made by Cassius A. Fisher. This work was not done with sufficient care to enable the section to be tied to the top of the Lee conglomerate, which is the key rock of the region, but the section seemed to be of sufficient importance to warrant publication.

COAL.

In attempting a general investigation of the western coal fields close attention was given to the study of the coal itself, as to its physical, chemical, and commercial properties. Such a study can be more profitably undertaken in these States than in the older and better-known fields of the East, for the reason that many single fields contain several grades of coal, and in the Rocky Mountain province as a whole all grades from lignite to anthracite are represented.

The study of the various kinds of coal has not progressed far enough to say what shall be the exact limits assigned to these grades, but the grades themselves are fairly well established and have been definitely adopted by the Geological Survey for use in its publications. They are as follows: (1) Anthracite, (2) semianthracite, (3) semibituminous, (4) bituminous, (5) subbituminous, (6) lignite. The first three are not common in the western fields, and their definition will not be attempted at the present time, further than to say that the common trade distinctions will be followed. The distinction between bituminous, subbituminous, and lignite is much more important in the West, and provisional definitions are given as follows:

Lignite: Brown, woody, or earthy coals which slack quickly on exposure to the atmosphere. Their moisture content is usually over 30 per cent, and their heating value is generally less than 8,000 B. t. u.

Subbituminous coal: Intermediate in quality between lignite and bituminous coal. It is generally glossy black, is relatively free from joints, and slacks readily on exposure to the atmosphere. Coal of this grade is usually called "black lignite," but it is not woody in appearance, and more nearly resembles bituminous coal than lignite. Its moisture content is usually over 10 per cent, and its heating value ranges from 8,000 to 11,000 B. t. u.

Bituminous coal: Bituminous coal hardly needs description, since it is the coal with which most persons are familiar. In a commercial way it is distinguished from subbituminous coal by its ability to withstand the weather.

CHEMICAL WORK.

For the purpose of classifying the coals and determining the values of the coal land, a great many samples were collected for analysis. In order to make comparisons with the analyses of coals from different fields and different regions and provinces, the sampling was done according to a uniform method, as follows:

1. Select a fresh face of unweathered coal at the point where the sample is to be obtained, and clean it of all powder stains and other impurities.

2. Spread a piece of oilcloth or rubber cloth upon the floor so as to catch the particles of coal as they are cut and to keep out impurities and excessive moisture where the floor is wet. Such a cloth should be about 1½ by 2 yards in size and spread so as to catch all the material composing the sample.

3. Cut a channel perpendicularly across the face of the coal bed from roof to floor, with the exceptions noted in paragraph 4, and of such a size as to yield at least 5 pounds of coal per foot of thickness of coal bed—that is, 5 pounds for a bed 1 foot thick, 10 pounds for a bed 2 feet thick, 20 pounds for a bed 4 feet thick, etc.

4. All material encountered in such a cut should be included in the sample, except partings or binders more than three-eighths inch in thickness and lenses or concretions of sulphur or other impurities greater than 2 inches in maximum diameter and one-half inch in thickness.

5. If the sample is wet it should be taken out of the mine and dried until all sensible moisture has been driven off.

6. If the coal is not visibly moist, it should be pulverized and quartered down inside the mine to avoid changes in moisture, which take place rapidly when fine coal is exposed to different atmospheric conditions. The coal should be pulverized until it will pass through a sieve with ½-inch mesh, and then, after thorough mixing, it should be divided into quarters and opposite quarters rejected. The operation of mixing and quartering should be repeated until a sample of the desired size is obtained. When the work has been properly done a quart sample is sufficient to send for chemical analysis. This should be sealed in either a glass jar or a screw-top can with adhesive tape over the joint, and sent to the chemical laboratory for analysis.

All chemical analyses were made at the laboratory of the fuel-testing plant of the Geological Survey, located at the Carnegie Technical Schools, Pittsburg, Pa. The analytical work was under the immediate charge of F. M. Stanton, who conducted the laboratory under the general direction of N. W. Lord, of the Ohio State University, Columbus, Ohio. Professor Lord's high standing as a coal chemist is sufficient guaranty of the accuracy of the analyses contained in this bulletin.

When a sample reached the chemical laboratory, it was given a serial number by which it could be recognized, and was pulverized and quartered down in the ordinary way for analysis. As the samples were taken in the mines and not allowed to dry before they were pulverized and quartered down, it is generally true that they contained more moisture than the commercial coal. Before attempting to analyze a sample it was deemed desirable to eliminate some of this excess moisture, and for this purpose the following apparatus was used:[a]

In order to make determinations of the loosely held moisture more uniform and definite, a special drying oven has been designed and introduced into the laboratory. In this oven samples of several pounds weight can be dried in a gentle current of air raised from 10° to 20° above the temperature of the laboratory. In this way the coal is air dried in an atmosphere with a very low dew-point and not subject to large percentage variations, and the results obtained are considerably more concordant.

The sample was then weighed, and the loss in weight is given as the "air-drying loss." The results of the analysis of this sample are the best for ordinary purposes, and are generally spoken of as the analysis of the air-dried sample. From this set of figures the analysis is easily recalculated back to the theoretical condition of the sample as

[a] Bull. U. S. Geol. Survey No. 290, 1906, pp. 29–30.

received, and this result is also given in the tables of analyses. In every case the two analyses are presented as a matter of convenience to the general reader, who may use either the analysis that represents coal as it came from the mine, with more or less mine water in its pores, or the analysis of the sample dried under nearly ordinary atmospheric conditions. It is believed that the latter more nearly represents commercial coal than the former, and also that it is more nearly comparable to analyses of samples collected in the ordinary way from stock piles or cars of coal and shipped to a laboratory in canvas sacks.

The heating power of the coal sample was determined by burning a small briquet in a Mahler bomb calorimeter and noting the amount of heat given off during the process. It is expressed in both calories and British thermal units (B. t. u.).[a] The calories may be converted into British thermal units by multiplying by 1.8.

A proximate analysis and a calorimetric determination were made on each sample sent to the chemical laboratory, and in special cases ultimate analyses were made in addition to those specified above. The comparative value of proximate and ultimate analyses is an extremely interesting subject, and it is to be hoped that the present work will go a long way toward showing the inadequacy and misleading character of the former and the great value of the latter, not alone for comparative purposes, but also as a base for economic calculations.

Up to the beginning of the fuel-testing work by the Geological Survey at St. Louis in 1904 very few ultimate analyses of coal had been made in this country. Fortunately Professor Lord, who had charge of all chemical work for the fuel-testing plant, had already learned the unreliable character of proximate analyses and had determined, wherever practicable, to make ultimate analyses. Lack of funds alone prevented him from making ultimate analyses of all samples received, but even with the limited means at his command several hundred such analyses of coal have been made. Time and space forbid a full discussion of this subject, but some of the shortcomings of the proximate analysis are the variable amount of volatile matter, dependent on the rapidity with which it is driven off (amounting in some samples to 20 per cent), and the fact that in many analyses of anthracite and other high-grade coal the total carbon in the ultimate is less than the so-called fixed carbon in the proximate. These points are discussed more fully in Bulletin 323.

The final paper in this volume is a bibliography by Willis T. Lee and John M. Nickles of the reports of the United States Geological Survey, exclusive of those on Alaska, that deal directly or indirectly with the subject of coal.

[a] Calory: Amount of heat required to raise 1 kilogram of water 1° C. British thermal unit: Amount of heat required to raise 1 pound of water 1° F.