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THE COAL FIELDS OF THE UNITED STATES

GENERAL INTRODUCTION

BY

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CONTENTS.

ILLUSTRATIONS.

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By Marius R. Campbell.

PURPOSE AND SCOPE OF REPORT.

The growing demand for fuel and the probability that sooner or later the United States will be called upon to furnish supplies to less favored countries has made it desirable for the Geological Survey to take stock of the country's fuel and to determine the quantity, quality, and geographic distribution of the coal still in the ground and available for future use. This report is intended to supply such information regarding the coal fields in the United States, arranged according to the States within which they lie.

The first effort to give to the public a comprehensive description of the great coal-bearing areas of the country was made by the Geological Survey in 1902, by the publication, in the Twenty-second Annual Report of the Director, of 12 papers dealing with the coal-bearing areas of the United States, including Alaska. Unfortunately, this series of papers, although exceedingly interesting and valuable as presenting a summary of the then existing knowledge of some of the coal fields, was lamentably incomplete, for it contained no description of the rich fields of Maryland, West Virginia, eastern Kentucky, and Virginia; and the treatment of many of the western fields was unsatisfactory, for the reason that they had not been examined in detail, and consequently their boundaries and their contents could be described in only a vague and indefinite manner.

Up to the year 1905 the United States Geological Survey had made no effort to examine and map systematically the coal fields of the country, especially of the West; but a number of fields had been specially examined or had been mapped as a part of the general plan of making a geologic atlas of the United States. This lack of activity in the examination of the coal resources was due largely to the lack of interest in such work shown by coal operators, owners, and consumers, as it was then generally regarded as unnecessary in the development of a coal-bearing tract to have any geologic information regarding the lay of the beds and the quality or quantity of the coal, and the consumer purchased his coal with but little thought as to whether or not he was getting the best available fuel for the particular use to which he expected to devote it.

About that time, however, the public began to awaken to the realization of the need of utilizing better the fuel supply and to the further realization that great frauds had been perpetrated in the Western States in procuring valuable coal lands under the homestead act and laws other than the coal-land law, which required the payment to the Government of not less than $10 or $20 an acre and restricted to 160 acres the area that it was possible for one person to acquire. In response to the public demand for the stopping of such frauds and for the better conservation of the fuel reserves of the country, President Roosevelt in 1906 withdrew from entry 66,000,000 acres of supposed coal land, and the United States Geological Survey was requested to classify these lands and appraise their value, so that they might be sold at prices that accorded with the quantity and quality of coal available in them. This was made possible by a new interpretation of the phraseology of the coal-land law of 1873, which specified that coal lands should be sold at not less than $10 an acre if more than 15 miles from any completed railroad and not less than $20 an acre if within 15 miles of a railroad.

In anticipation of this action the Geological Survey had begun in 1905 the systematic examination of coal fields in the public-land States and by 1908 had made sufficient progress in that work to issue the first reasonably accurate map of the coal fields of the country, on a scale of about 120 miles to the inch. In addition to outlining the coal fields, this map differentiates the areas of known coal from the areas that might possibly contain valuable coal and shows also those areas in which the coal-bearing rocks are under deep cover. On this map the coal fields are classified according to the rank of the coals they contain, or at least three great groups are recognized, namely, (1) anthracite, semianthracite, semibituminous, and bituminous coal; (2) subbituminous coal; and (3) lignite. In addition to delineating the coal fields, the map contains an estimate of the tonnage of coal still remaining in the ground and supposedly available for the future needs of the country.

The making of this estimate, crude though it was, marked an important step in the investigation of the Nation's resources, for it was the first attempt to make a quantitative estimate that would enable the public to calculate the length of time the fuel supply might be available. The writer in making this estimate was painfully aware of its inaccuracies and of the fact that even in such old coal-mining States as West Virginia the data were in such shape that an accurate estimate was impossible. Curiously enough, the data available at that time were much more complete for the Western States than for the Eastern States, and the estimates for some of those States were therefore much more accurate. The figures were put forth at that time with two objects in view—first, to give the public the benefit of the best estimate that the Geological Survey was able to make, and, second, to stimulate the activity of others who were working on the same problems. The publication served both its purposes, for the figures were widely used in the conservation discussions that were then being carried on; and a number of State geologists of the older States began to make estimates of their coal resources, with the result that a much greater volume of information became available and much better estimates could be made. Naturally, the estimates made by the writer on entirely insufficient data were modified considerably when additional information was obtained; but for a number of years the result stood nearly as it was originally made.

The next attempt to improve upon the old maps of the coal fields and the estimates of the reserves they contained was made by the writer on invitation of the executive committee of the International Geological Congress for its twelfth session, at Ottawa, Canada, in 1913. The International Geological Congress had several years before decided to consider at each session some subject of world-wide interest, particularly some mineral resource in which all countries would be interested. Thus iron ore was considered at the eleventh session, which was held at Stockholm, Sweden, in 1910, and a monograph summarizing the knowledge then existing on this subject was published. The executive committee decided to take up the subject of coal for consideration at the twelfth meeting, at Ottawa, and the results are incorporated in three large volumes of descriptive text and an atlas showing the coal fields of the world. These volumes are a storehouse of information, but their small edition and great cost make their general distribution impossible. Naturally, in a report covering a subject as important as coal and dealing with the fields of the entire world, each country must be treated so briefly that the description may be considered only a short summary.

The report on the coal fields of the United States, exclusive of Alaska, appears by comparison with some others contained in these volumes to be exceedingly brief—too short, in fact, to afford the ordinary reader the information he desires. The essential features of this report are (1) the map, which was brought up to date for this particular purpose, but which is on a scale too small to be of much practical value; and (2) an estimate of the reserves of the different ranks of coal in the several fields, regions, and provinces. This estimate is the most recent one that has been prepared, and it will be accepted with some modifications for the present report.

Although the volumes published by the Twelfth International Congress are monumental and constitute a remarkable achievement, it was at once realized that they are very inadequate for practical use and that they should be supplemented by more detailed reports on all the countries as soon as possible. Since the publication of the descriptions of the coal fields of the United States in the Geological Survey's Twenty-second Annual Report, in 1902, a large amount of geologic work has been done in the coal fields of this country. The Survey has each year mapped, either in a reconnaissance way or in detail, many thousands of square miles of coal territory in the public-land States of the West, and in addition has been carrying on detailed work in many of the eastern fields. Owing to administrative demands, the work in the West was at first largely of a reconnaissance character, but as time passed it was found necessary to refine methods and to do more careful work, so that in the end sufficient data would be available for a fairly accurate valuation of the land according to the quantity of available coal it contained, a valuation which should be of use to anyone interested in the development of the fields, either as owner, operator, or investor.

In the East the Geological Survey has been or is cooperating with State organizations in the careful survey of parts of the eastern fields. Such work has been carried on in Pennsylvania, Tennessee, and Alabama and is now in progress in Virginia, Illinois, and Kentucky. The State geological surveys of Maryland, West Virginia, Ohio, Tennessee, Iowa, Missouri, and Washington have been active, and good reports have been published relating to the coal in those States.

In view of the great amount of work that has been done since the previous summary was made, it seems opportune to sum up again the existing knowledge regarding the extent and quality of the coals in the various fields. In order to give this report the greatest value and standing, it is proposed, so far as practicable, to have the description of each natural area prepared by the geologist who is most familiar with the field and best acquainted with the local conditions. Not only will this plan be followed within the United States Geological Survey, but State geologists have been invited to prepare the accounts of the coals in their respective States, so that the report may be thoroughly authentic. The State geologists of Maryland, West Virginia, Ohio, Tennessee, Michigan, Illinois, Iowa, Kansas, and Washington have agreed to contribute to this plan, and this cooperation insures excellent results.

As the reports are to be prepared by many authors, it is impossible to assemble all the material at one time, so the State reports will appear as separates as soon as they are ready and will then be included in the final volume or volumes. Where the coal-bearing areas of a State are made up of a number of isolated fields or regions each isolated area will be treated separately in a signed report, and the State separate will be made up of papers dealing with the fields comprised within the State.

RANKS OF COAL.

METHODS OF CLASSIFICATION.

In this report the word "rank" will be used to designate those differences in coal that are due to the progressive change from lignite to anthracite, a change marked by the loss of moisture, of oxygen, and of volatile matter. This change is generally accompanied by an increase of fixed carbon, of sulphur, and probably of ash. When, however, one coal is distinguished from another by the amount of ash or sulphur it contains, this difference is said to be one of grade. Thus "a high-grade coal" means merely one that is relatively pure, whereas "a high-rank coal" means one that is high in the scale of coals, or, in other words, one that has suffered devolatilization and that now contains a smaller percentage of volatile matter, oxygen, and moisture than it contained before the change occurred.

Within the boundaries of the United States there are all ranks of coal, from the coarse, woody lignite of North Dakota and eastern Montana to the highest rank of anthracite in the fields of eastern Pennsylvania. From the earliest days of coal mining in this country it has been recognized that coals differ greatly, not only in the percentage of ash which they contain, but also in their inherent composition. Although the latter distinction was recognized, little or no attempt was made to determine the reason for the difference or the criteria for fixing the limits of different groups of coals. The first serious attempt in this country to devise a scientific basis for the classification of coal was made by Persifor Frazer, jr., of the Second Geological Survey of

Pennsylvania, under the direction of J. P. Lesley. Frazer[1] listed most of the commercial coals of the State and then compared the trade distinctions with the "fuel ratio" (the quotient of the fixed carbon divided by the volatile matter of the proximate analysis). He found that there were in use at that time the rank names of anthracite, semianthracite, semibituminous, and bituminous. He found that in practice the fuel ratios of the coals of the different groups overlapped, but he concluded that these ranks might be established with the following limits:

	Fuel ratio.
Anthracite	100 to 12
Semianthracite	12 to 8
Semibituminous	8 to 5
Bituminous	5 to 0

These ranks, with the boundaries fixed provisionally by Frazer, serve very well for Pennsylvania and for the coals of the great Appalachian trough, extending from northern Pennsylvania to central Alabama, but they do not apply to the great mass of western coals, which at that time were of little or no importance. Most of those persons who were instrumental in developing the coal fields of the West originally came from the East, and they carried with them ideas of coal obtained in the eastern fields, which contained high-rank fuel. Not only that, but most of the coals in the Appalachian region and those in the upper Mississippi Valley are of Carboniferous age and hence are very old; but the coals of the West are Cretaceous and even Tertiary in age and hence, when compared with Appalachian coals, are very young indeed. A difference in character was recognized, and as the western coals are generally inferior they were lumped together and called merely "lignite." The term "lignite" is undoubtedly appropriate for many of the low-rank coals of the West, but it is certainly not appropriate for black, shiny coals that show little trace of woody texture and are capable of producing a coke of fairly good quality. Nevertheless such coals were called lignite and relegated to the lowest rank among coals.

Several persons have attempted to devise schemes of classification based upon chemical composition by which a certain coal could be referred to its proper place merely by means of its chemical analysis, but so far no scheme of this kind has been devised that is applicable to all ranks of coal. Some scheme like Frazer's suits admirably one part of the column but can not be made to fit the other part. Schemes of this kind are so unsatisfactory that the United States Geological Survey has finally decided that it is practically impossible to classify all ranks of coal according to their chemical composition, and that it is necessary to supplement chemical by other criteria. Accordingly, Frazer's scheme, with some necessary modification to make it agree more closely with modern trade practices, has been adopted for the higher ranks of coals, and physical characteristics have been used for the lower ranks. Thus, in the West no one questions that there is coal of the rank of lignite, but it is difficult, if not impossible, to specify what a lignite is in terms of its chemical constituents. Similarly, in the Rocky Mountain region, where the low-rank coals are abundant, there is no question that there is a difference between brown, woody, or amorphous lignite and shiny, black subbituminous coal, but this difference is one that is not clearly defined by available chemical criteria. There is, however, a marked physical difference, although there is no sharp line of demarcation between them. Thus subbituminous coal is black and shiny, whereas lignite is dull and generally woody in texture; subbituminous coal has a greater heating value and carries less moisture than lignite. Altogether the difference between the two is so marked that they are known by different names in the trade, and for that reason, if for no other, they should be classed differently.

In a like manner the distinction between subbituminous and bituminous is not sharp and does not show in a chemical analysis. Subbituminous coal generally carries more moisture than bituminous, but there are so many exceptions to this rule that it has very little value as a means of distinction. There is, however, one marked difference by which they can always be separated, and that is the difference in their behavior under weathering, and as this difference has a marked effect upon their commercial value and use it seems to be a legitimate criterion for separating them into the two ranks, subbituminous and bituminous. The difference in the effect of weathering is due primarily to a difference in the percentage of moisture in the coal, but, as stated above, the

[1] Pennsylvania Second Geol. Survey Rept. MM, p. 143, 1879.

percentage of moisture is variable. Subbituminous coals, however, in general contain more moisture than bituminous coal, and on weathering lose their moisture readily. This loss of moisture results in shrinkage and the formation of incipient cracks, which do not conform to the few joint faces but tend to run irregularly. On the other hand, the bituminous coals generally contain a smaller percentage of moisture, so that they shrink very little when they are suddenly dried. They may be very highly jointed and may fall to pieces readily when mined and handled, but their breakage is due to the inherent weakness of the coal, and the cracks almost invariably correspond with the joint faces.

By using these criteria (part chemical and part physical) it is possible to classify coals and not only to define the general characters of the different groups but to delimit them with considerable accuracy. The United States Geological Survey recognizes the ranks indicated below.

ANTHRACITE.

Anthracite is generally well known and may be defined as a hard coal having a fuel ratio (fixed carbon divided by the volatile matter) of not more than 50 or 60 and not less than 10. Most of it is mined in eastern Pennsylvania, where its peculiar quality is due to regional metamorphism—that is, to the crushing stresses that affected the crust of the earth when the rocks were thrown into the great folds that characterize this region. Small areas of anthracite occur in the West, but generally these coals have been converted to anthracite by the heat of some mass of igneous rock that was thrust into the other rocks while it was in a molten condition. Many such masses take the form of thin sheets, which were forced in between the beds of the other rocks, and consequently for some distance they may lie parallel with the coal beds. If a coal bed is cut by the igneous rock, it may be burned to ashes, made into coke, or converted to anthracite. The product will depend on the presence of air, the intensity of the heat, and the length of time the coal was subjected to the influence of the heated mass. Anthracite is an almost ideal domestic fuel, but it is not well adapted to steam raising unless an absolutely smokeless coal is needed. Many people believe that anthracite has greater heating value than any of the other ranks, but this is not true, as can be seen by a comparison of analyses given on page 31, and by reference to figure 1 (p. 8). Largely on account of its low heating power anthracite is not an economical fuel for steam raising or for use in general manufacturing.

SEMIANTHRACITE.

Semianthracite is also a hard coal, but it is not so hard as true anthracite. It is high in fixed carbon, but not so high as anthracite. It may be defined as a hard coal having a fuel ratio ranging from 6 to 10. The lower limit is uncertain, as it is difficult to say where the line should be drawn to separate "hard" from "soft" coal and at the same time to divide the two ranks according to their fuel ratio. Some hard coals of the anthracite type have a fuel ratio as low as 6.5 or 7, whereas some of the soft coals have a fuel ratio as high as 7 or perhaps more. For this reason it is probable that fuel ratio alone can not be depended upon to separate these two ranks, but that physical properties also may have to be taken into consideration. The change of ordinary soft coal to semianthracite is due to the same causes that produced anthracite, except that the process has not been carried so far in semianthracite, possibly because the action has not been so intense. There is very little semianthracite in this country, so it is only a small factor in the coal trade. Such semianthracite as is mined reaches the consumer generally under the name "anthracite" and is masquerading under false colors.

SEMIBITUMINOUS.

The name "semibituminous" is exceedingly unfortunate, as literally it implies that this coal is half the rank of bituminous, whereas it is applied to a kind of coal that is of higher rank than bituminous—really superbituminous. Semibituminous coal may be defined as coal having a fuel ratio ranging from 3 to 7. Its relatively high percentage of fixed carbon makes it nearly smokeless when it is burned properly, and consequently most of these coals go into the market as "smokeless coals." The best coal of this type has a heating value greater than that of any of the other ranks and is consequently best adapted to raising steam and to general manufacturing that requires a high degree of heat. It is regarded as the best coal for steamship and especially for naval use, as it is nearly smokeless and requires less bunker space per unit of heat than other coals. The coal is generally minutely jointed and is therefore tender and friable. In fact, it is so friable that in mining a large percentage of fine coal is produced, and in transportation many of the lumps are broken to pieces, so that by the time it reaches the consumer, especially if it has been transshipped, it is generally in small pieces. This fineness is by many regarded as detrimental, because the public is accustomed to lump coal which will stand transportation without crushing, but when this coal is used with mechanical stokers and with a grate adapted to its use the fineness of the coal is not disadvantageous. The great bulk of this kind of coal is in the eastern fields, but some is found in the West, where it has been subjected to a slight amount of regional metamorphism or has been heated by some igneous mass.

BITUMINOUS.

The term "bituminous," as generally understood, is applied to a group of coals having a maximum fuel ratio of about 3, and hence it is a kind of coal in which the volatile matter and the fixed carbon are nearly equal; but this criterion can not be used without qualification, for the same statement might be made of subbituminous coal and lignite. As noted before, the distinguishing feature which serves to separate bituminous coal from coals of lower rank is the manner in which it is affected by weathering. Bituminous coal is only slightly affected chemically by weathering unless it is exposed for many years, and then, although it consists of small particles, each particle is a prismatic fragment, whereas coals of lower rank break into thin plates parallel with the bedding.

The definition given above might not indicate that the bituminous rank is a large one, but when it is examined critically it is found to contain a great variety of coals—coals having really little in common with one another. Many attempts have been made to subdivide this great group, but so far no scheme proposed has met with general approval. Many of the better coals of this group will coke or are being coked, but coking coals are not limited to the bituminous rank, for some of the best coke made in the United States is produced from semibituminous coal. Not only is the upper limit of the coking group uncertain, but the lower limit is equally difficult to determine. If the coking property had some definite relation to the chemical composition of the coal as it is at present determined there might be some hope of establishing a class of coking coals by chemical analysis, but no one can say just why a coal will coke, so an actual test in an oven is required to determine whether or not a coal will coke.

Gas coals have been in great demand and such coals must be high in volatile matter, so as to make on distillation a large volume of gas; and as this gas must be relatively free from sulphur the coal from which it is made must contain a very small percentage of that element. In recent years the making of gas for illuminating and heating has undergone a great change, water gas largely taking the place of the gas distilled from coal; and as this gas requires no particular quality of coal, the demand for "gas coals" has been greatly reduced and probably in the near future will disappear.

Cannel coal is very rich in volatile matter, is generally high in hydrogen, and therefore burns with a great heat and a long flame. It is essentially a gas-making coal and in the early days was used extensively for this purpose, as well as for the distillation of oil. As a source of oil it could not compete with petroleum derived from wells, and soon after oil was discovered in the earth in 1859 the business of distilling oil from coal in this country was discontinued. Cannel coal owes its richness to the fact that it is composed almost entirely of the spores, spore cases, seed coats, and resinous or waxy products of such plants as lived at the time of the existence of the coal swamp. In such swamps, as in those of to-day, there was doubtless in places open water, into which the spores and seed cases floated and, becoming water-logged, sank to the bottom and in time produced cannel coal. The absence of woody material in such coal gives it a regular texture and grain that are not found in any other coals. As a result, it breaks like glass, with a conchoidal or shell-like fracture, and owing to its richness in inflammable material the best of it will ignite readily when a lighted match is held in contact with a small splinter of it. As the nature of cannel coal is due to the kind of material of which it is composed, it follows that there may be all kinds of cannels, corresponding in a general way with the various ranks of coals. Ashley[1] has recently proposed the following classification of cannel coal:

1. Subcannel coal:
   (a) Brown subcannel, of brown coal or lignite rank.
   (b) Black subcannel, of subbituminous rank.
2. Cannel coal, of bituminous rank:
   (a) Boghead cannel (fuel ratio less than 0.5).
   (b) Typical cannel (fuel ratio between 0.5 and 1).
   (c) Lean cannel or semicannel (fuel ratio more than 1).
3. Canneloid, semibituminous coal, semianthracite, or anthracite.

Cannels which are of the rank above bituminous have lost their original richness and therefore do not deserve to be called cannels.

Other kinds of coal, such as "block" and "splint," are recognized in the trade, but the characteristics of these coals are physical and are found in only a small group of coals. Some of the "block" and "splint" coals are very hard, almost as hard as anthracite, but they are generally woody in texture and contain much mineral charcoal. They are valuable coals in the market, but usually their development is so local that they are not of much importance in a general classification of coal.

As the great group of bituminous coal includes all grades from the poorest western bituminous coal to the highest-rank coal in the Appalachian region, exclusive of the semibituminous coal, the writer has, for convenience, divided the group and represented it on the general map of the coal fields of the United States in two colors—one indicating all coals having, in the air-dried sample, a calorific value (in British thermal units) of more than 12,500, and the other indicating all bituminous coals having, in the air-dried sample, a calorific value of less than 12,500. This is a practical separation according to heating value, which, after all, is the principal criterion for determining the relative values of coals.

SUBBITUMINOUS.

The term "subbituminous" is adopted by the Geological Survey for what has generally been called "black lignite," a term that is objectionable because the coal is not lignitic in the sense of being distinctly woody, and because the use of the term seems to imply that this coal is little better than the brown, woody lignite of North Dakota, whereas many coals of this rank approach in excellence the lowest grade of bituminous coal. Subbituminous coal is generally distinguishable from lignite by its black color and its apparent freedom from distinctly woody texture and structure, and from bituminous coal by its loss of moisture and the consequent breaking down or "slacking" that it undergoes when subjected to alternate wetting and drying. As the percentage of moisture is an important matter in buying and shipping coal, and as the slacking on exposure to the weather makes it necessary to ship in box cars and to guard carefully against spontaneous ignition, there is a great commercial difference in these two kinds of coal which the Geological Survey has recognized by putting them in different ranks. Despite the many drawbacks in the shipment and use of subbituminous coal it has found a ready market in much of the western country, because it is a very clean domestic fuel and ignites with little difficulty.

Subbituminous coals differ considerably in chemical composition and in physical appearance. Some are banded like much of the bituminous coal, and some are essentially cannel in physical and chemical make-up. In general, the Cretaceous and younger coals of the West contain a smaller percentage of sulphur than the older coals of the East, and as some of them are high in volatile matter they would doubtless be excellent coals for making gas, either illuminating gas or producer gas for generating power.

LIGNITE.

The term "lignite," as used by the Geological Survey, is restricted to those coals which are distinctly brown and either markedly woody or claylike in their appearance. They are intermediate in quality and in development between peat and subbituminous coal. As the moisture of lignite as it comes from the mine generally ranges from 30 to 40 per cent, its heating value is low; and the consumer can not afford to pay freight for any great distance on so much water. Also it parts with much of this moisture very readily when exposed to the weather and so falls to pieces or slacks much

[1] Ashley, G. H., Cannel coals in the United States: U. S. Geol. Survey Bull. — (in preparation).

more readily and completely than subbituminous coal. On this account it is more likely to ignite spontaneously and must be handled even more carefully than subbituminous coal and stored in a place where it will not be exposed to alternate wetting and drying. Lignite is mainly marketed near the mine, as a domestic fuel, but at a few places in North Dakota and Texas it is shipped to near-by towns and used for general manufacturing purposes.

At the Government testing plant at the St. Louis Exposition North Dakota lignite was found to be an excellent fuel for making producer gas, and probably in the future it will be

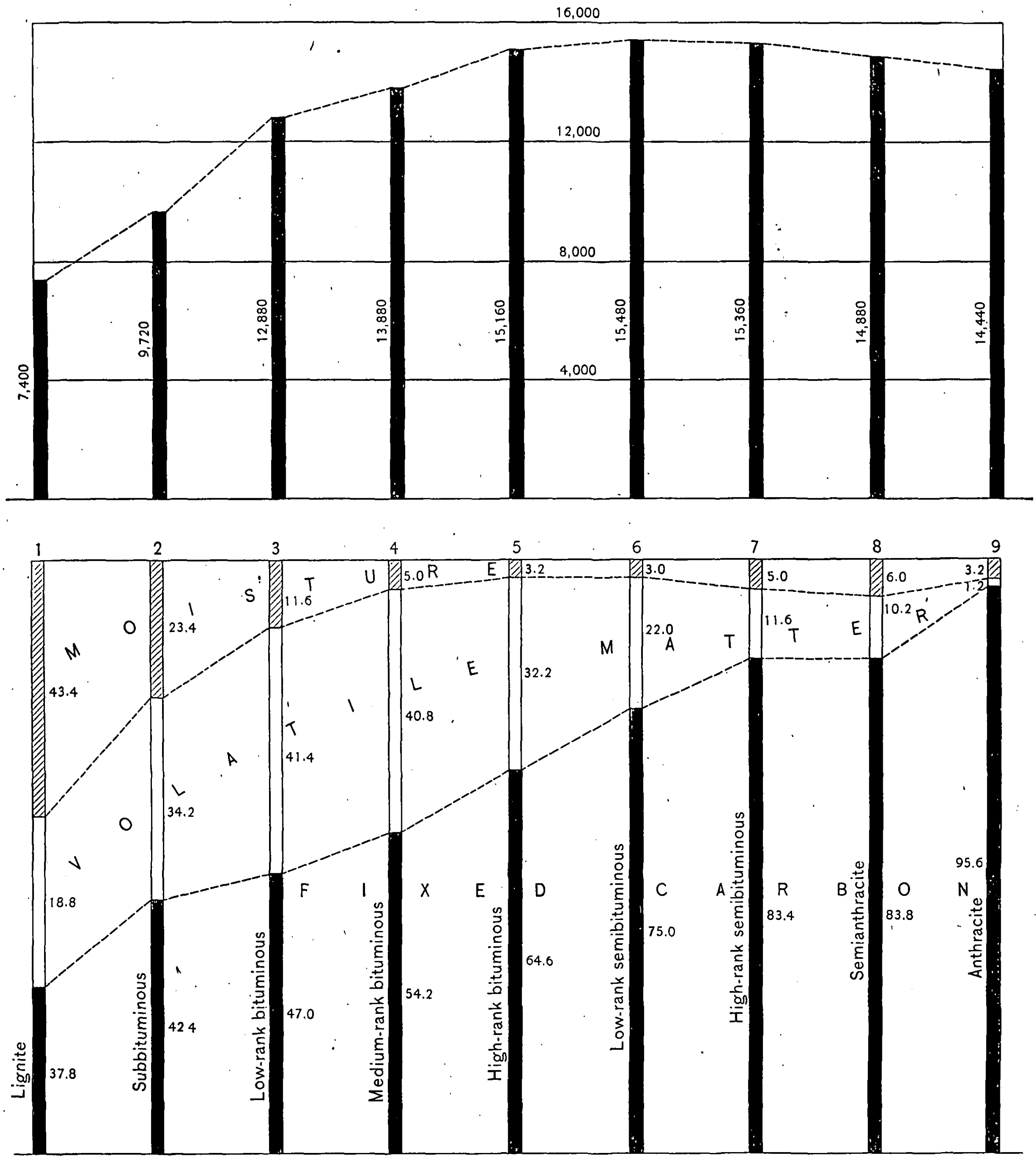

FIGURE 1.—Diagrams showing the chemical composition and heat efficiency of the several ranks of coal. Upper diagram: Comparative heat value of the samples of coal represented in the lower diagram, computed on the ash-free basis. Lower diagram: Variation in the fixed carbon, volatile matter, and moisture of coals of different ranks, from lignite to anthracite, computed on samples as received, on the ash-free basis.

much more largely used for producing power than it has been in the past. Just how this will be accomplished is difficult to determine, but it is possible that large producer plants may be erected at the mines and the lignite converted into electric energy and delivered by long-distance transmission lines to towns within a radius of 200 miles or to the railroads in this region or in contiguous territory. Lignite has recently been used in powdered form, and it may possibly be better utilized in this way. As some of the Texas and Arkansas lignites are in effect undeveloped cannel coals, it seems possible that when the supply of petroleum is much less than the demand, the lignite may be used for the distillation from it of oil and the various by-products that are now obtained in Scotland from oil shale. Lignite can also be manufactured into hard briquets, which make an excellent fuel, but so far the cost of manufacture has been prohibitive.

COMPARISON OF THE DIFFERENT RANKS.

Figure 1 is a graphic representation of the proximate chemical composition of the various ranks of coal and of their heat-producing values. The lower diagram shows the fairly regular increase in fixed carbon from lignite to anthracite, though it must not be supposed that the lines for all coals are as simple as those shown in the diagram. The analyses upon which the diagram is based are, however, actual analyses selected from those given in the table at the end of this introduction. No. 1 represents the analysis of a typical North Dakota lignite which as it comes out of the mine has a moisture content of about 40 per cent. It also contains about 5.5 per cent of ash, but as ash varies irregularly without regard to the rank of the coal the analysis has been recalculated to the ash-free basis, thus eliminating ash from consideration. All the other analyses have been similarly recalculated. No. 2 represents a subbituminous coal from Wyoming, having a moisture content of 23.4 per cent; Nos. 3, 4, and 5 represent various ranks of bituminous coal, the lowest one being from Indiana, the second from Ohio, and the third, or highest, from the Pittsburgh district of Pennsylvania; Nos. 6 and 7 represent semibituminous coal from the Windber district of Pennsylvania; No. 8 represents semianthracite; and No. 9 represents some of the best anthracite of the Pennsylvania region. The diagram shows clearly that the fixed carbon increases very markedly from lignite to anthracite; that the moisture of the higher-rank coals is small and about the same quantity in each, but increases rapidly from medium-rank bituminous coal to lignite; and that the greatest development of volatile matter is not at either end of the series but in the lower ranks of bituminous coal.

The upper diagram represents the heat value of the same coals on a similar ash-free basis. There is a very general misconception regarding the heat value of anthracite as compared with that of lower-rank coals. Many persons think that because anthracite commands a higher price it must necessarily be a better heating coal than the soft varieties, but this diagram shows conclusively that it is not and that the best coal for heat production is No. 6, or low-rank semibituminous coal. Anthracite commands a higher price than soft coal because of its suitability for domestic use and because of its freedom from smoke, soot, and waste.

From the diagram it might be inferred that the heat value of a coal depends directly upon the amount of fixed carbon that it contains, but this can not be true, for the heat value of pure carbon is only 14,580 British thermal units,[1] whereas coal No. 6 has a heat value of 15,480 British thermal units. Coal derives its heat value mainly from two elements, carbon and hydrogen, the carbon having a heat value of 14,580 British thermal units and the hydrogen a heat value of 62,000 British thermal units.[1] The greater heating power of the low-rank coals as compared with anthracite is due to the fact that these coals contain a considerable quantity of available hydrogen,[2] which when burned produces a much greater heat than the same weight of carbon.

Either diagram well illustrates the slight value of lignite as compared with the higher-rank coals and makes it possible to understand that Pennsylvania and West Virginia coal can be hauled by rail to Lake Erie,

[1] Richards, J. W., Metallurgical calculations, p. 16, 1906.

[2] W. S. Parr (The composition and character of Illinois coals: Illinois Geol. Survey Bull. 3, p. 37, 1906) defines available hydrogen as follows: "By available hydrogen is meant that part of the hydrogen content which is free to enter into combination with oxygen for the production of heat, as distinct from that hydrogen present which already has * * * the necessary equivalent oxygen for the formation of water, and consequently [is] noncombustible."

shipped by vessel to Duluth or Superior, hauled 400 or 500 miles inland, and then sold in direct competition with lignite mined in the vicinity.

CLASSIFICATION OF THE COAL AREAS OF THE UNITED STATES.

For convenience in describing the areas underlain by coal-bearing rocks, some scheme of names and classification of areas is essential. The plan adopted is shown in Plate I, the large map in the pocket of this report. Although coal areas might be subdivided or combined indefinitely, the Geological Survey recognizes four classes, which, beginning with the smallest, are called district, field, region, and province.

COAL DISTRICT.

"Coal district" is a term applied only to developed coal areas. It is already in common use in the trade for an area in which mining has been developed around a fairly definite center, but it also has been loosely used as synonymous with "coal field." A district is generally small, and the term is restricted to areas in which mines are developed continuously on a given bed or beds, and the coal is generally known in the trade by some distinguishing feature, such as a trade name, or by some physical characteristic upon which it is advertised and sold. Districts are generally named from the leading town in them, or from the town at which mining first started or which first achieved distinction in producing this particular kind of coal. From the very nature of the case districts are small, but it is not possible to set definite limits to the area that should be classed as a district.

COAL FIELD.

A coal field is an area of coal-bearing territory next larger than the district. Its recognition is based less upon trade practices and uses than that of a coal district, and therefore it has more of the natural features to characterize it. The term "field" is at present used very loosely, and in many ways it is not advisable to attempt its close restriction. As used by the Geological Survey, it is applied to an area generally larger than a district, but still to a well-defined compact area. In this respect it differs from "region," the term for the next higher division. Small areas or basins that are separated from one another or from the main coal area are called fields, especially if their coal is of fairly uniform composition and value. "Field" is also applied to a certain area which has become prominent because of the kind of coal it produces, but which is not necessarily limited to certain centers of production. Some of the best-known fields of this class are the Pocahontas field of Virginia and West Virginia, the New River field of West Virginia, the Georges Creek field of Maryland and West Virginia, and the Windber field of Pennsylvania. These fields have definite outlines, corresponding with the extent of the bed or beds of coal upon which the field was established or with the limits of coal of a certain quality that influences its sale and use. In large areas of coal-bearing rocks, like that of Illinois, there are many districts or centers of production, but it is also necessary to recognize the larger divisions corresponding with those just mentioned. In Illinois, however, there are no well-defined limits depending on quality of coal or upon natural features, for the region is fairly well and uniformly developed and the quality of the coal does not vary markedly throughout the State. Under such conditions it would be of little value to mark off definite fields, and they would not be used by many; therefore it has been decided that in such areas fields may be recognized as a matter of convenience and hence may vary in different reports, for a division that would be convenient to one person would not necessarily suit the needs of another. It is therefore proposed to consider such a State as Illinois as made up of an indefinite number of coal fields, the limits of which should be defined by the person making the subdivision, and the limits made by one person should not necessarily agree with or control those made by another.

COAL REGION.

As a matter of convenience, coal fields may be grouped into larger divisions called "regions." Such grouping is generally designed to bring together coal fields that have some feature or features in common, thus enabling them to be considered as a whole or separately as the problem may demand. The most striking subdivision of a region is in Colorado and New Mexico, where the great area of coking coal in the eastern parts of these States extends across the line from one State into the other. The Colorado portion is well known as the Trinidad field and the New Mexico portion is equally well known as the Raton coal field. Both names are appropriate and needed, but in many discussions it is necessary to consider them together as a unit, for they are as nearly a unit as it is possible for two coal fields to be. For this reason they are here considered together as the Raton Mesa coal region. Likewise, many other areas are essentially a combination of fields and therefore should properly be classed as regions. Good examples are the anthracite region of Pennsylvania; the western coal region in Iowa, Missouri, Kansas, Oklahoma, and Arkansas; and the numerous deep basins of the Rocky Mountain States.

COAL PROVINCE.

As fields are grouped into regions, so regions are grouped into much larger divisions, called "provinces." These, as shown on the accompanying map, are the Eastern province, Interior province, Gulf province, Northern Great Plains province, Rocky Mountain province, and Pacific Coast province. The grouping into provinces is made largely for convenience in considering broad questions of geologic age, geologic structure, quality of coal, and transportation. In a province, as in a smaller division, there is a certain amount of unity in the physical features of the coal fields of the province or in the quality of the coal. Some provinces contain all ranks of coal, and the fields are grouped together because of their geographic positions, their structural features, or the age of the coal beds.

THE COAL AREAS.

EASTERN PROVINCE.

The Eastern coal province contains probably nine-tenths of the high-rank coal of the country. It is considered as made up of the anthracite regions of Pennsylvania and Rhode Island, the Atlantic coast region of Virginia and North Carolina, and the great Appalachian region, which embraces all the bituminous and semibituminous coal of what is generally known as the Appalachian trough.

The Rhode Island anthracite region, although known since 1760, is of little economic importance, for the coal has never been mined for a long period on a commercial scale, and judging from its composition and the metamorphism of the surrounding rocks, it seems doubtful whether it will ever have more than a local value, if it is worked at all. The coal is more highly metamorphosed than that of Pennsylvania, so that some of it is mined and sold as graphite. It also carries a large percentage of ash, which makes it an expensive fuel to mine and to use.

The Pennsylvania anthracite coal region is so well known that it needs little mention here. It is described in detail in the chapter on the coal fields of Pennsylvania. In the trade generally the anthracite region is considered as made up of four fields known as the Northern, Eastern Middle, Western Middle, and Southern. In 1914 these fields together produced 90,821,507 short tons, or 99.9 per cent of the anthracite mined in the United States.

The Atlantic coast region is of very little practical importance at the present time, for its coal beds are worked either not at all or on a scale so small as to be negligible. The Richmond field or basin, however, has the distinction of being the scene of the first development of bituminous coal in this country, mining having been begun there in 1787. The coal is generally of high rank, some being semianthracite; but the conditions of mining are not good, and the coal can not at present compete with the better coals of the Appalachian region.

The Appalachian region is the greatest storehouse of high-rank coal in the United States, if not in the world. This near-by almost inexhaustible supply of high-grade fuel has been the foundation of the development of the blast furnaces, the great iron and steel mills, and the countless manufacturing enterprises of the Eastern States. The Appalachian region is a compact area of coal-bearing rocks, which in general lie in a deep trough. The trough shape is well marked in its northern part, and the middle line or axis runs nearly through Pittsburgh and thence southwestward to the vicinity of Huntington, W. Va., on Ohio River. The lowest coal bed, if present in the deepest part of the trough, would be about 2,000 feet below the surface. The rocks in this great trough are thrown into a large number of minor wrinkles or anticlines (upfolds), especially on its southeastern side. These small folds generally bring to the surface the harder rocks just beneath the coal-bearing beds, and consequently they form ridges or mountains, as they are called in Pennsylvania and West

Virginia. These die out toward the southwest, but they exert a marked effect upon the coal beds exposed at the surface as far south as Kanawha River. In southern Virginia and Kentucky the trough flattens very decidedly, and as a consequence the coal beds are not so deep, but their outcrops cover a wider territory. In Tennessee the trough character is scarcely apparent and the coal-bearing rocks appear to be nearly horizontal but are broken up by several small folds similar to those noted in the northern part of the region. The effect, however, is very different, for owing to the flatness of the rocks the streams have cut away the upbending folds, leaving great longitudinal valleys instead of anticlinal ridges, and narrow, flat, intervening troughs of coal-bearing rocks. The same kind of structure, except that the troughs are more pronounced, is seen in the coal fields of Alabama, but toward the southwest the rocks gradually descend, and near Birmingham they begin to pass beneath the later rocks (Cretaceous) that were deposited on the Gulf Coastal Plain. This cover becomes deeper and deeper toward the southwest, until, in the vicinity of Tuscaloosa, the coal-bearing rocks disappear and nothing is in sight but the soft sand and clay of the younger formations.

Along the western margin of the Appalachian region the coal beds dip very slightly toward the east and there are no outliers of any consequence, but on the eastern margin the rocks are much more severely folded and there are many synclines (downfolds), which, by the cutting back of the river valleys, have been separated from the main area and now form isolated natural fields. Among the most prominent of such outliers on the east side are the Broad Top field, in central-southern Pennsylvania; the Georges Creek and Upper Potomac basins, in Maryland and West Virginia; the Lookout Mountain field, in Georgia and Alabama; and the Coosa and Cahaba fields, in Alabama. There are also a number of long, narrow outliers in southern Virginia, which properly do not belong with the Appalachian region but which for convenience will be so classed. These fields contain thin and irregular coal beds of Mississippian ("Lower Carboniferous") age. They are the only coals of this age and are the oldest coal beds of commercial importance in the country. Many of them are of high rank, but on account of their irregularity and impurity they have not been extensively developed.

The coal of the Appalachian region is generally of high rank but shows considerable variation, mainly in an east-west direction. In the reports of the Second Geological Survey of Pennsylvania it was clearly pointed out that the percentage of fixed carbon in the coals of that State increases from west to east, and also that the volatile matter decreases in the same direction. The result of this progressive change is that the coals on the eastern margin of the region are of much higher rank than are those on the western margin. White[1] has recently shown that the same progressive change is characteristic of the entire region, and he has drawn contours of equal percentages of fixed carbon showing the change. The well-known fact that the fields of semibituminous coal are limited to the eastern margin of the region accords with this progressive devolatilization of the coals toward the east. Even along this margin they are irregularly disposed, and White has shown that this irregularity is due to variation in the pressure exerted on the coal-bearing rocks at the time of the great movement which folded the rocks of the Appalachian region. As this thrust was transmitted through broken and folded rocks it acted irregularly; in places the movement was taken up by the folding and faulting of the rocks, and in other places the thrust was transmitted direct to the coal-bearing rocks, and materially affected the quality of the coal. As the coals are the softest rocks involved in the thrust, they were transformed according to the intensity of the pressure, the transformation being greatest along the east side of the region, where the thrust was most severe, and least along the west side, where the thrust was least. Two other elements that materially affect the quality of the coal of a field or region are the sulphur and the ash. The variations in the quantity of these substances are due to original differences in the conditions under which the coal was laid down and to conditions that permitted mineral-bearing waters to circulate through the coal bed since it was formed. These conditions can not be determined, so the variations in composition due to these factors can not be foretold to any great extent.

[1] White, David, Some relations in origin between coal and petroleum: Washington Acad. Sci. Jour., vol. 5, pp. 189-212, 1915.

During the deposition of the coal beds the Appalachian region was doubtless a great swampy country near sea level, but even then it appears to have been in the form of a basin, whose deepest part was in western West Virginia. On account of this depression there was probably open water here, at least during part of the time when the coal beds were being deposited, for the coals are generally absent from this part of the region, as is shown by the map (Pl. I, in pocket). These beds, if present, would be deeply buried, but their absence has been revealed by deep drilling done to find oil and gas.

INTERIOR PROVINCE.

The Interior province includes all the bituminous coal fields and regions near the Great Lakes, in the Mississippi Valley, and in Texas. It is made up of four distinct regions—the northern region (Michigan); the eastern region (Illinois, Indiana, and western Kentucky); the western region (Iowa, Missouri, Kansas, Oklahoma, and Arkansas); and the southwestern region (Texas).

As these regions, with one exception, are not near mountainous uplifts, the coals are of low rank, for little pressure has been exerted upon them, and their change or devolatilization has been only such as resulted from the long-continued pressure of the overlying rocks. This statement is eminently true of the northern and eastern regions, the Iowa and Missouri portions of the western region, and the southwestern region; but as the southern part of the western region is near or a part of the mountainous area of uplifted rocks in Arkansas, the coal beds have been materially affected. They have been devolatilized to about the same extent that the Appalachian coals have been devolatilized by the great pressures that folded the rocks of the Appalachian Valley. The Ouachita disturbance changed the coal of Arkansas to semibituminous coal, or even to semianthracite, and the pressure has been effective as far west as a point about 50 miles within Oklahoma. Beyond this point the coal has not been converted into semibituminous coal but has been considerably altered, so that to-day it is regarded as superior to the coals of adjacent fields. The pressure also has devolatilized the coals farther north, in Kansas, changing them to coals of considerably higher rank than the coals of the region farther north. The coals of the northern part of this province have a large moisture content, which of course produces low heating value and a generally poor coal.

The northern and eastern regions are in the form of wide, generally shallow basins in the coal-bearing rocks, the deepest parts of which lie near their centers, toward which the beds dip lightly from the margins. The coal-bearing rocks in the western and southwestern regions do not lie in basins, or rather they constitute the eastern margin or rim of the greatest basin on the continent—the basin of the Great Plains. Throughout Iowa, Missouri, Kansas, Oklahoma, and Texas the coal-bearing rocks dip lightly westward and pass beneath the later rocks of the Great Plains. They emerge in the Rocky Mountains, on the west side of the Great Basin, but here the rocks of this age are not coal bearing, and no one knows where the change occurs from one to the other. The passing of the coal-bearing rocks under the cover of the later rocks of the Great Plains is shown on the map by the dotted pattern in the light tint. That part of the western region which lies in Arkansas is merely an eastern outlier in which the rocks are greatly folded, and in which the coals are therefore much devolatilized and improved in rank; but this area is still connected with the main region to the west.

Although the coal of the Interior province as a whole is not equal in quality to that of the Eastern province, it is very extensively mined and is used for heating and for generating power in the many cities and towns of the Mississippi Valley and the Great Lakes. In fact, the presence of these extensive coal fields in near proximity to the rich agricultural lands of this country and to the avenues of transportation—railroads, lakes, and rivers—has been largely instrumental in developing the great manufacturing centers of Chicago, St. Louis, and Kansas City and has been an important factor in the development of the railroad systems that gridiron this fertile country in all directions.

GULF PROVINCE.

The Gulf province is at present of slight commercial importance. The coal is mostly lignite, and it has been mined at only a few localities in the State of Texas. The same

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kind of lignite occurs in Arkansas, Mississippi, and Alabama; but, owing to the presence of high-rank coal near by in the fields of Arkansas, western Kentucky, and Alabama, it has not been prospected except in a few areas. The lignite is contained in rocks of Eocene (early Tertiary) age, generally sandstone and clay, that are so soft as to make mining difficult and expensive.

The old idea that lignite is of recent formation and is of low rank because of that fact is generally true, but there are many exceptions. Some of the most valuable coal beds in the Western States are of the same age as the Texas lignite, yet they are of high rank. A study of the coal fields of the United States shows clearly that, although age is a factor in the alteration of coal, it is generally not the principal one.[1] The controlling factor is the presence or absence of disturbances in the rocky crust of the earth, either in the coal field or close to it. Thus in the lignite fields of Alabama, Mississippi, Arkansas, and the northern part of Texas there have been no mountain-making disturbances since the lignite was formed. It may be said that the region is in its native condition; but near the Mexican border, in the vicinity of Laredo and Eagle Pass, the coal has been changed to a higher rank by the uplift of the Sierra Madre Oriental, of Mexico, which lies only a short distance to the southwest. Similarly, in Washington and in other States of the West the disturbances which have produced the mountains have so changed the coal that, instead of being lignite, it is now bituminous coal or even anthracite. The lignite of northern Texas and southern Arkansas is of better quality than that of the central part of Texas, the difference being due probably to the different conditions under which it was deposited. The lignite in the southern part of Texas seems to have been formed largely of trees and stems, which are clearly visible in the lignite to-day; but in the northern part of the State there appears to have been open water in which the accumulation of organic matter consisted mostly of spores, seeds, and spore cases that grew on the plants in the surrounding areas. Such wood as fell or drifted into the water decayed, for the most part, so that its resin contents fell to the bottom, there to mingle with the spores and other resistant detritus. The result is that this lignite is very rich in bituminous matter; it is sub-cannel coal or cannel coal in the process of formation. The rocks containing the lignite dip gently toward the Gulf and pass under younger rocks. These effectually conceal the Eocene rocks and the beds of lignite, but it does not seem probable that the lignite extends very far in this direction, for when the lignite was formed this area was a low coastal plain, which sloped gently to salt water, and as the swamps were limited to the land area they were probably not very wide.

NORTHERN GREAT PLAINS PROVINCE.

The Northern Great Plains province includes all the coal fields in the Great Plains east of the Front Range of the Rocky Mountains. In this province the rocks generally lie flat or are but little disturbed, and in consequence the coals are of low rank, being either lignite or subbituminous, except in a few of the basins near the mountains, where the forces that caused the upheaval have locally changed the coal to higher rank. This progressive increase in rank toward the regions of mountain making is apparent in this province, as may be seen not only by comparing the coals of the different fields or basins, but by comparing many of the coals within a basin, region, or field.

The largest coal region in this province is the Fort Union region, lying in North Dakota, South Dakota, Montana, and Wyoming. The northeastern part of this region consists of a very broad, flat basin, in which the dips on the margin are so slight as to be perceptible only by the aid of a level. The southwestern extremity is more sharply folded, consisting of a rather broad, flat trough lying between the great upfold of the Bighorn Mountains on the west and the lower dome of the Black Hills on the east. Although the Fort Union region incloses the Black Hills in a great semicircle the coals there show little or no effect of that uplift, but they do show a decided change toward the Bighorn Mountains. Thus throughout North and South Dakota and northeastern Montana the coal is a brown woody lignite with a moisture content, as it comes out of the ground, of 40 to 45 per cent, but in the vicinity of Miles City, Mont., the brown lignite begins to lose its apparently woody structure and to take on the black color and the general appearance of a subbituminous coal. The change is, however, very gradual, and throughout a zone 15 or 20 miles in width can be seen the mingling of the two types; probably no two geologists would agree on the position of the line marking the place where one leaves off and the other begins. The subbituminous coal in southern Montana is of very poor quality, but farther southwest, in Wyoming, it improves until it reaches its best development in the vicinity of Sheridan, Wyo., where it has been mined extensively for a number of years. At this place the moisture content of the coal as it comes from the mine is only about 25 per cent, and for this reason alone its heating value is 30 per cent higher than that of the lignite of North Dakota.

Many of the coal beds in the Fort Union region are thick, those that are worked measuring from 3 to 40 feet. In almost every section of land that has been carefully examined there have been found a number of thick beds, so that the quantity of unmined coal or lignite in this region is very great.

The lignite and subbituminous coal of this region, as well as that of most of the other fields and regions of this province and of the Rocky Mountain province, ignite easily, and many of them have been burned along the outcrop. Some of the beds are now on fire and are objects of curiosity to those who are not familiar with the country. The heat generated by the burning has been in many places so intense as to partly fuse the overlying shale or sandstone, producing a peculiar, slaglike material of a deep-red color. In other places the heat has not been sufficient to melt the adjacent rock but has changed its color to a dull red, resembling that of brick. Red hills and ridges, whose color is due to the burning of the coal, are common in the western fields and are considered indications of the former presence of coal beds. The depth to which burning extends depends on the depth of cover, for the coal can burn only to depths to which air is accessible; consequently burning is generally limited to a few hundred feet. This low-rank coal also ignites easily in mining, and many mines have had to be permanently abandoned because of fires.

There is very little mining in the Fort Union region, because the inhabitants are engaged chiefly in raising stock and farming, and there are no large towns or cities in which much manufacturing is carried on. The absence of manufacturing explains in part the lack of mining, but the greatest drawback to the establishment of mines is the poor quality of the lignite, which precludes its use as a fuel in many manufacturing processes. Although winter in this region is very severe and fuel is in great demand, those who have attempted to mine the lignite have found difficulty in marketing it in competition with high-rank Pennsylvania and West Virginia coal shipped over the Great Lakes and thence by rail to the lignite region. In the southwest end of the region, where the coal is of the subbituminous rank, the operators have been more successful in opening mines and in building up a large trade. The two centers of production are Sheridan and Glenrock, near Douglas, Wyo., and the coal mined around these centers finds a ready market, especially in the north, where better coal is difficult to obtain.

Although the coal in that part of the Fort Union region which surrounds the Black Hills shows little effect of the upheaval that formed the hills, the coal found immediately on the flanks of the uplift shows a decided improvement in quality as a result of the formation of the Black Hills. The region containing this high-rank coal is rather small and lies entirely on the west side of the uplift. The coal is contained in rocks of Lower Cretaceous age and corresponds with the coal mined at Sand Coulee, south of Great Falls, Mont. The principal center of development is at Cambria, north of Newcastle, Wyo. The coal is of bituminous rank and has been used largely in the manufacture of coke. The coal bed, however, has many partings of shale, and both the coal and coke therefore contain so high a percentage of ash that they can not easily compete with the lower-rank coals of adjacent regions.

Coal like that of the Sheridan district, though perhaps of somewhat better quality, is rather extensively mined in the Bull Mountain field, on Musselshell River. This field is comparatively new, its development dating from the building of the Pacific coast extension of the Chicago, Milwaukee & St. Paul Railway, in 1908. The field is small, having an area of about 1,000 square miles, but it includes a number of beds, some of which attain considerable thickness. The coal is of the same geologic age as the lignite in the eastern part of Wyoming and in North Dakota, but here it has been changed to a high-rank subbituminous coal, about equal to the best subbituminous coal of the Northern Great Plains and Rocky Mountain provinces.

In the Milk River valley and along Missouri River south of the Bearpaw Mountains there is considerable coal, but the beds are generally thin or are only locally expanded into beds thick enough to be of present commercial value. Another obstacle to the development of these fields is the deep cover of glacial drift, which, north of Missouri River, makes the tracing of coal beds and their exploitation very uncertain. The coal is generally subbituminous, but in places it is of the bituminous rank.

The highest-rank coal in this part of the province is that in the Great Falls and Lewistown fields, of Cascade and Fergus counties, Mont. This coal is bituminous and for a number of years was mined and coked at Belt to supply the copper smelters at Anaconda. The coking coal is limited, however, to this locality, and the manufacture of coke from it was discontinued several years ago. The coal contains a large percentage of impurities and has therefore not met with as ready a sale as was expected when the mines were first opened. The coal is mined somewhat extensively for steaming and domestic use in the region round about the mines.

Farther south, in Colorado, the next field of consequence is generally known as the Denver region. This region extends from the Wyoming line southward as far as Colorado Springs. The coal is extensively mined northwest of Denver and to some extent at Colorado Springs. It is subbituminous and finds a ready market in and about Denver and Colorado Springs as a domestic fuel. The coal northwest of Denver is mined along the upturned edge of the coal-bearing rocks at the foot of the mountains, and here it is a fairly good coal of its class; but that at the southern end of the region appears not to have been so greatly affected by the uplift of the mountains and is consequently of much lower rank.

The Canon City field is a small basin of coal-bearing rocks in the great reentrant of the mountain front at Canon City. Owing to its proximity to the mountain uplift the coal has been changed to the bituminous rank, but it carries so high a percentage of ash that its sale in competition with cleaner coals is difficult, especially for domestic use. In the early days of railroad building in Colorado (about 1878) there was keen rivalry between the Denver & Rio Grande and Santa Fe railroads for the possession of this field as a source of locomotive fuel, but although both roads gained access to it the coal has been somewhat disappointing, as its heavy ash content makes it an undesirable fuel for this purpose. Many mines have been opened, and the coal reaches a large market along the mountain front.

The Raton Mesa region, in the southern part of Colorado and the northern part of New Mexico, contains the most valuable and highest-rank coal in this province. The Colorado portion is generally known as the Trinidad field and the New Mexico portion as the Raton field. The rocks lie in a basin-shaped structure, but the edge next to the mountain is sharply upturned and broken through by the old volcanic stock and dikes of the Spanish Peaks. As this basin is filled with younger rocks to a depth of at least 7,000 feet the coal-bearing rocks are deeply covered, and mining has been limited largely to the eastern margin of the region. By the great stresses produced in the folding of the rocks, and possibly by the heat evolved from the stocks and dikes of igneous rocks, the coal has been so much altered as to become of higher rank than any other coal found in this province, except possibly that of the Black Hills. The coal in the southern part of the region makes excellent coke, and the product of the ovens supplies most of the smelters in the Rocky Mountain province.

ROCKY MOUNTAIN PROVINCE.

Until within a few years the coal resources of the Rocky Mountain coal province were largely unknown except a few areas of high-rank coal in Colorado and neighboring States, which were exploited by some of the large steel companies or railroad corporations. Since 1905 the United States Geological Survey has examined most of these fields, either in reconnaissance or in detail, and now the fields of this province are almost as well known as those of the Eastern or Interior provinces.

The coal-bearing formations of the Rocky Mountain province are of Cretaceous and Tertiary (Eocene) age, and doubtless originally extended in almost unbroken sheets throughout the province. Since the deposition of the earliest of these beds the province has been greatly disturbed by movements in the crust of the earth, which resulted in the formation of great mountain ranges. The areas between the ranges were either depressed or remained stationary while the movement was in progress, so that great intermontane basins or depressions lie in the mountainous region. Most of these basins are floored with coal-bearing rocks of either Cretaceous or Tertiary age or are underlain by such rocks at a greater or less depth. In many basins the coal is not so deep but that it may in the future be reached by deep shafts; but in a few it lies so deep that it probably can never be mined.

The Rocky Mountain province contains a greater variety of coal than any other province in the United States. The coal ranges from lignite to anthracite and includes all the ranks described in this paper, though the prevailing ranks are subbituminous and low-grade bituminous. The coal is mined rather extensively, the greatest centers of development being Red Lodge, Mont.; Rock Springs and Kemmerer, Wyo.; Crested Butte and Durango, Colo.; Castlegate and Sunnyside, Utah; and Gallup, N. Mex.

In Montana the coal fields of the Rocky Mountain province are neither large in area nor of great commercial importance. Persistent efforts have been made to develop the fields that contain the best coal, especially in the vicinity of Livingston, at Trail Creek, Chestnut, and Electric; but for various reasons mining has not been successful, and the only mine now in operation is a small one in the Trail Creek field. The coal in these fields is bituminous and has been coked near Livingston and Electric, but the beds are thin and greatly disturbed, and the coal is too dirty to compete with other coals in the market.

Many of the areas shown on the map (Pl. I) are small basins in lake beds in the mountain valleys, which contain in places thin beds of lignite. These are probably of Miocene (later Tertiary) age.

The most important area in this part of the State is the Red Lodge field, which, so far as Montana is concerned, might be considered in the Northern Great Plains province, because it lies east of the Front Range of the Rocky Mountains, but it is also the northern continuation of the Bighorn Basin region of Wyoming, which lies west of the Bighorn Mountains, a range that is generally considered the easternmost range of the Rockies, and for that reason the Red Lodge field is here treated as a part of the Rocky Mountain coal province. The coal of the Bighorn Basin is mostly subbituminous, but that in the lower coal-bearing formation, at the north end of the basin, in the vicinity of Bridger, Mont., is bituminous. The subbituminous coal, however, is of excellent quality, especially that mined at Red Lodge and Bear Creek, at the north end of the basin, and at Gebo, near the south end, and compares favorably with the best subbituminous coal of the Rocky Mountain province.

The coal-bearing rocks outcrop in a narrow belt about the great basin and near the foothills of the surrounding mountains. They dip toward the center of the basin, where, as is indicated on the map, they are deeply covered with other rocks that were deposited later. It is estimated that the coal beds near the center of the basin may lie as much as 10,000 feet below the surface. The irregularity in the thickness of the coal beds and the fact that few railroads have been built within the basin have led to the development of only two mining centers, one at Red Lodge, Mont., in the north end of the basin, and the other at Gebo, Wyo., in the south end of the basin.

The Wind River Basin is of much the same character as the Bighorn Basin, except that the late Tertiary formations more nearly conceal the coal-bearing rocks. For this reason less is known regarding the coal beds, which have been mined in only a small way. The coal is subbituminous and compares favorably with the coal of the same rank in adjacent fields. A little coal has been mined in the vicinity of Hudson. The coal in the middle of the basin lies under thick cover and is probably too deep to be profitably mined.

The Green River region is a great irregular basin in southwestern Wyoming, in which the Rock Springs dome rises like an island in the sea. This region contains, besides the Green River Basin proper, a basin lying between Rock Springs and Rawlins, which extends southward and terminates in a point near Steamboat Springs, Colo. The rocks of this basin include four coal-bearing formations, which are generally well exposed in the upturned rim and in the Rock Springs dome, near the center of the basin. Several kinds of coal occur in the basin, ranging in rank from subbituminous to anthracite. The Tertiary rocks contain subbituminous coal, the Cretaceous rocks subbituminous and bituminous coals, and where these have come in contact with igneous sills, as they have northwest of Steamboat Springs, Colo., anthracite has been formed. The coal at Rock Springs, Wyo., may be regarded as the best type of bituminous coal in this region, and coal of about the same quality occurs along Little Snake River, in Wyoming, and also in the valley of Yampa River, between Hayden and Steamboat Springs, Colo. In the Green River Basin the coal beds are so deeply buried by later formations that it is doubtful whether they can ever be mined. The principal mines are in and about Rock Springs, Wyo., and in the valley of Yampa River below Steamboat Springs, Colo.

This enormous basin, which extends from Rawlins on the east to and beyond Grainger on the west, and from the Wind River Mountains on the north to Yampa River on the south, is one of the largest and most important coal regions in the Rocky Mountain province. It embraces an area of about 17,000 square miles and contains four coal-bearing formations, each of which carries from four to twenty coal beds, ranging in thickness from 2 feet to 20 or 25 feet. It is true that the coal in many areas of this region lies so deep that it may never be worked, but after excluding all such areas it is estimated that at least 6,000 square miles is underlain by coal beds that can be mined when the demand for fuel is sufficient to warrant the expenditure necessary for sinking deep shafts. The quantity of coal in the ground in this region is enormous, probably exceeding that in any other region of similar area in this country. There are only two centers of mining in the Green River region. The most important is Rock Springs, Wyo., on the Union Pacific Railroad, where mining has been carried on since that road was completed in 1869. The other mining center has recently developed in the vicinity of Steamboat Springs, Colo., on the Denver & Salt Lake Railroad ("Moffat road").

West of the Green River Basin is the Hams Fork coal region, which consists of a number of folds of coal-bearing rocks. These extend nearly northward from the southwest corner of Wyoming for a distance of 200 miles. The coal is high-rank bituminous and subbituminous. The coal beds vary considerably in thickness, the largest one of subbituminous rank measuring at one place 84 feet of clear coal. This is the thickest coal bed that has been mined or prospected at the surface in the United States. Somewhat thicker beds have been reported in drill logs in other regions, but the uncertainty of determining the thickness and character of beds penetrated by a churn drill renders such a report of doubtful value. The greatest center of mining is at Kemmerer, Wyo., and this coal is regarded as the best that is produced in the State.

East of the Green River Basin is the Hanna field or basin. This basin lies just back of Laramie Mountain, or the Front Range, and is named for Hanna, Wyo., the principal town and the center of the mining industry. The coals are of low rank, being generally subbituminous but possibly including some bituminous coal that is not yet developed. The character of the coal probably explains the meagerness of the mining operations in this field, as the coal can not hold its own, except for local uses, in competition with the better fuel of Rock Springs, on the west, or some of the Colorado coals, on the south.

South of the Uinta Mountains lies a great, irregular basin-shaped coal region, which is called the Uinta region. It extends eastward and southward from the Wasatch Plateau and terminates in a spoon-shaped point near Crested Butte, Colo. The coal-bearing rocks form the rim of this great troughlike depression. From the rim they dip toward the middle and are there deeply buried by later formations. The coal varies considerably in quality, being best at the two extremities of the region. The coals in the vicinity of Crested Butte have been greatly altered, partly by the mountain-building forces and partly by the volcanic material that has been poured out in this area, and as a consequence some of the coal is high-grade anthracite and some belongs to lower ranks. On the rim, especially to the north, the coal changes within a short distance to subbituminous, and this rank characterizes the coal along the north rim. The coal on the south rim is generally bituminous, and west of Green River it improves rapidly in quality and increases in quantity to Castlegate, Utah, where there are many beds of high-grade bituminous coal, as shown on the map (Pl. I).

The coal beds of the Uinta Basin are not so numerous nor so extensive as those of the Green River Basin, to the north, but even this basin contains an enormous quantity of coal. The area of the basin is about 16,500 square miles, a little less than the area of the Green River Basin, and the part in which the coals are accessible for mining is about 5,750 square miles. The coal beds are most numerous at the two extremities of the region, and naturally those parts contain the greatest quantity of coal. At Newcastle, on Grand River, 109 feet of coal in workable beds has been measured, and the beds at the western extremity are probably just as thick. The thickest bed reported is 40 feet, but beds that measure from 6 to 15 feet are fairly common. The center of mining in the western part of the basin is Castlegate, Utah, where the coal is of excellent quality, and some of it is being coked for use in smelters. The centers of mining in the eastern part of the basin are Crested Butte, where both bituminous coal and anthracite are mined extensively, and Newcastle, on Grand River, a few miles below Glenwood Springs. The coal at Newcastle is generally subbituminous, but a short distance to the south it changes to bituminous and some of it is coked.

The coal-bearing rocks at the west end of the Uinta Basin turn to the south in the Wasatch Plateau, and for convenience of discussion this area is treated as a separate field. The same coal beds that occur in the vicinity of Castlegate, in the Book Cliffs, are found in the cliffs that form the eastern front of the Wasatch Plateau, and the coal is of about the same rank and thickness. The coal beds in the high cliffs that form the east front of the Wasatch Plateau are nearly horizontal and are well exposed in every canyon that cuts this rim. The plateau has a width of about 25 miles, but the coal beds are not exposed along its western margin, because the rocks on that side dip to the west and pass below later formations.

Most of the coal of this field occurs in the Mesaverde formation, but some is found near the base of the Mancos shale. Coal is not generally found in this shale in the Rocky Mountain province, but toward the southwest this lower coal-bearing formation becomes more and more important, and in the next fields to the south it is the principal source of supply.

The Colob and Kaiparowits plateau fields lie at the south end of the Wasatch Plateau, near the south line of Utah. The coals of the Colob Plateau have been examined in considerable detail, but those of the Kaiparowits Plateau are known only from casual inspection and from reports of persons who have traveled through that remote region. The coal of the Colob Plateau occurs near the base of the Mancos shale and is of bituminous rank. It lies high on the plateau and is therefore accessible with considerable difficulty. Its disadvantageous position has not, however, prevented its development, but it has been mined only to supply local needs. A small outlier of the field in Iron County, west of Cedar City, contains anthracite, but the coal is dirty and probably can not compete with the lower-rank but cleaner coals of the Colob Plateau.

The coal in the lower part of the Mancos shale is reported to occur in fairly thick beds in the vicinity of Paria, but no examination has been made to determine their quality or extent. In the Kaiparowits Plateau, northeast of Paria, beds of coal 12 or 15 feet thick have been opened in the face of the cliff and coal has been mined for local use. This coal is in the Mesaverde formation, which probably extends unbroken from the Wasatch Plateau on the north, but in the intervening area it is so covered with lava that the actual connection has never been traced. The quality of this coal has not been determined, but it is probably bituminous and of about the same rank as that in the plateau farther north.

The San Juan River region lies south of the San Juan Mountains, partly in Colorado and partly in New Mexico. It is a great basin-shaped depression with a prolongation running southward through the town of Gallup, on the Santa Fe Railway. Two coal-bearing formations are involved in the folding that produced the basin—the Mesaverde formation at the base and a part of the so-called "Laramie" which has recently been named the Fruitland formation[1] at the top. Both formations are of Upper Cretaceous age; the lower one under-

[1] Bauer, C. M., Contributions to the geology and paleontology of San Juan County, N. Mex.—1, Stratigraphy of a part of the Chaco River valley: U. S. Geol. Survey Prof. Paper 98, p. 274, 1916.

lies the entire basin, but the upper is restricted to the part of the basin that lies north and east of Chaco River. The depth of the coal-bearing rocks in the center of the basin has not been determined but is probably several thousand feet. The rocks on the rim of the basin dip toward the center; in the northern part the dip is rather steep, but in the southern part it is so gentle that it can scarcely be detected by the unaided eye.

The coal in the lower formation is generally of better quality than that in the upper formation, but each has felt the effects of the movements that resulted in the upheaval of the San Juan Mountains. The coal is normally subbituminous, but around the north rim the lower coal has been changed by the pressure into bituminous coal that in places is good enough to coke. The upper coal is less altered, but toward the east it also is changed to bituminous coal. South of San Juan River all the coal in both formations is subbituminous except possibly some on the east rim, which has been affected by the uplift of the Nacimiento Mountains. The coal beds of the Mesaverde formation range from 3 to 6 feet or more in thickness wherever they have been mined or prospected, and they are exposed at the surface throughout a wide expanse of country, extending from the rim of the basin north of the Santa Fe Railway on the south to Chaco River on the north and across the entire width of the basin in the other direction. The coal beds of the Fruitland formation, although they contain coal of lower rank, are thicker, especially in the northern part of the basin, where they have a known maximum thickness of 40 feet. Such a bed is exposed in the banks of Animas River below Durango, Colo., but the bed is badly broken by partings which would make mining expensive and detract greatly from the value of the coal.

The north and south sides of the basin have railroad connection, and in these parts the coal is mined, but the mines on the north side are handicapped by having to ship their coal over two mountain ranges and those on the south side have to handle a low-rank fuel, which can not easily compete with coal of a higher rank in near-by fields. Despite these drawbacks and the keen competition of fuel oil, the mines have managed to keep in operation, and the coal meets with a ready though local sale.

The Black Mesa field of Arizona is entirely undeveloped and is therefore largely unknown, except locally. It lies in the Hopi and Navajo Indian reservations and is about 75 miles distant from the nearest railroad point. The coal beds are in the Mancos shale and the Mesaverde formation, both of Upper Cretaceous age. The rocks lie in the shape of a broad, flat basin, forming a plateau upon which some of the Hopi Indian villages are built. The coal is subbituminous but of excellent quality and is used locally for the Indian schools.

Besides the main fields and regions noted above, there are a number of isolated outliers of coal-bearing rocks, mainly in New Mexico and Arizona, that are too small and unimportant to be considered here individually. Some of them, like Los Cerrillos, Carthage, and Capitan, in New Mexico, have been developed to some extent, because they contain coal of a better quality than could be found in many of the larger regions. Thus Los Cerrillos has for many years produced a fine grade of anthracite from a coal bed that has been locally changed by the heat of a sill of igneous rock, and the Carthage field has yielded coking coal. Most of these small fields are comparatively insignificant and will not be described further.

PACIFIC COAST PROVINCE.

The coal in the Pacific Coast province is limited largely to the State of Washington. Both California and Oregon have small fields within their borders, but the coal is generally of low rank or poor quality, and but little mining has been attempted. Washington, on the other hand, is fairly well supplied with coal in the western part, where it is most needed for the various industries that have been developed about Puget Sound. The coal-bearing rocks of Washington have been so greatly folded and contorted and then so deeply covered with glacial drift that it is possible to separate only a few of them into well-marked fields, and according to the local practice they are therefore generally subdivided arbitrarily according to the county in which they occur. The local practice will be followed here.

The coal fields of King County lie on the west side of the Cascade Mountains, extending from tidewater in the vicinity of Renton, 12 miles southeast of Seattle, to the foot of the mountains on the east. The thick cover of glacial drift and the almost impenetrable forest make coal prospecting laborious and difficult except near the principal streams, where these obstructions have been to some extent removed. The coal-bearing rocks are of Eocene (Tertiary) age and correspond in time of deposition with the lignite of the Dakotas, Montana, and Texas. In Washington, however, mountain-building forces have been so active in late Tertiary time that many of the coals have been changed from lignite to subbituminous, bituminous, and even to anthracite. In general, the coals nearest the Cascade Mountains are the most altered. The mountain-building forces not only changed the character of the coal but also folded and broke the rocks in a most intricate manner, so that in places mining is difficult and expensive. The coal beds generally dip at considerable angles and are locally broken and displaced, so that it is difficult to follow a coal bed in mining. The old swamps in which the coal was deposited were apparently subject to many floods, which washed mud and sand in from the surrounding higher lands. These materials settled to the bottom of the swamp, forming a shale or sandstone layer or parting in the coal bed, which to-day detracts greatly from its value, for the shale or sandstone must be removed before the coal can be marketed, and its removal is generally difficult and expensive. If the coal is put on the market after it is simply screened, it will contain a large percentage of ash, which makes it difficult to sell. The lump coal is generally so treated and reaches the market in fairly good condition, but in many places the fine coal is too dirty for marketing and must be washed before it can find purchasers. All coals contain more or less foreign material, in the form of partings or binders, but the coal of Washington includes more of such partings than the coal of many other parts of the United States.

The coals of King County are of subbituminous and bituminous rank in about equal proportions. The best coal in the county, to judge from the heating value of the pure coal, occurs along the mountain front from Snoqualmie on the north to Cumberland, a little south of Palmer Junction, on the south, embracing a belt of country not more than 3 or 4 miles in width. West of this belt lies a similar belt of good coal, which, however, has a lower heating value than that of the belt just mentioned; and then west of all is a belt of indefinite width in which the coal is subbituminous.

Many large mines are developed in this county, especially in the higher-rank coals near the mountain front, but some of the subbituminous coals, owing largely to their position on or near tidewater, are extensively mined, the coal finding a ready market as a domestic fuel.

The coals of Pierce County are the best in the State, but the known productive territory is very much smaller than that in King County. All the coals of this county so far mined or prospected are of bituminous or higher rank. The coal districts may roughly be divided into two groups—(1) the Wilkeson-Carbon Hill and adjacent districts, containing mainly high-grade bituminous coal but also some semibituminous coal, much of which will coke; and (2) the Melmont, Fairfax, and Montezuma districts, containing coal having a fuel ratio ranging from 2½ to more than 6. Thus most of these coals come within the rank of high-class bituminous and semibituminous coal. The coal at Wilkeson is the only coal in the State that has been extensively coked. All these coals bear an excellent reputation in the market.

The coal-bearing rocks in the fields of Pierce County are even more strongly folded and faulted than those of King County, on the north. Many of the coal beds are cut by dikes that ray out from the great volcanic center of Mount Rainier. The coal beds are exposed mainly in the deep canyons cut by Carbon River and its tributaries and consequently have been mined mainly along that stream. The mines are only a short distance from tidewater at Tacoma, with which they are connected by a branch line of the Northern Pacific Railway that was long ago built into this field for the purpose of obtaining fuel for use in locomotives.

All the developed coal of Kittitas County is in the Roslyn field, which is a regular, shallow basin in the vicinity of Cle Elum, in the valley of Yakima River, on the east side of the Cascade Mountains. The basin is not complicated by minor folds and faults, as are those on the west side of the mountains, and hence mining conditions are almost ideal. The coal is a hard, blocky coal of fairly uniform quality, well adapted to shipping and handling. It has been extensively used by the Northern Pacific Railway for locomotive fuel. It is mined by slopes and drifts on the outcrop and by shafts in the middle of the basin.

The coal fields of Thurston and Lewis counties are neither so well known nor so well developed as those of the counties just mentioned, largely because the coal of better rank near the mountains is in many places deeply covered with lava flows, glacial drift, and almost impenetrable forests. The coal in this region near the mountains is of high rank, in many places anthracite, but the complicated folds into which the strata have been bent and the abundance of partings in the coal beds make it impossible to mine the coal at a profit. The developed fields in these counties lie farther from the mountains, along the railroad lines leading from Tacoma, Wash., to Portland, Oreg. The coal beds in this part of the region are comparatively undisturbed and lie in an almost horizontal position. The coal, not having been subjected to the pressures that were exerted farther east when the mountains were uplifted, is of low rank. Those who have examined it most carefully are undecided whether to class it as lignite or subbituminous coal. It lies close to the dividing line between those two ranks and has generally been classed as subbituminous. It contains a large percentage of moisture, slacks badly when exposed to the atmosphere, and is little if any better as a fuel than Texas lignite. The extent of this low-rank coal has not been accurately determined, but it probably extends southward to Columbia River.

The coal fields of Whatcom and Skagit counties are perhaps less extensive than those of the counties so far considered. The coals in these counties range in rank from subbituminous coal at Bellingham to anthracite at Glacier. The anthracite lies in the valley of Glacier Creek northwest of Mount Baker and compares favorably in quality with some of the anthracite of the East. It has not yet been produced on a commercial scale, but mines are being opened, and it may soon be put on the market. High-rank coal has been mined and coked at Blue Canyon, in Whatcom County, and at Cokedale, in Skagit County, but these plants are now abandoned. The oldest mining operation in this region was at Bellingham, where a bed of subbituminous coal 14 feet thick was mined extensively about 30 years ago. On account of the low rank of the coal, the mine was soon abandoned, and now very little coal is mined in either Whatcom County or Skagit County. The rank of the coal, like that of all other coals in this country, decreases away from the mountains.

There are a number of small fields or isolated occurrences of coal in other counties, but they are of little importance and will not be described here.

Only a little coal occurs in Oregon, and that is of poor quality. Mining has been done in a commercial way only in the Coos Bay field, on the coast, in the southern part of the State. The coal in this field is subbituminous and has done little more than to supply the small local demand. Although there is considerable coal in this field, it is difficult to mine, and much of it lies below the waters of the bay. The field is not promising and probably never will be a large producer.

The best coal so far discovered in Oregon is in the Eden Ridge field, in the southern part of Coos County. The rocks are somewhat more disturbed here than in the vicinity of Coos Bay and the coal is of higher rank. It is bituminous, and some of it will coke, but the beds are full of shale partings, which make the coal very dirty. The field has no railroad connection at the present time, and consequently no mining has been undertaken.

Coal has been noted near Medford, in Jackson County; in the Nehalem Valley, in Columbia County, and in other parts of the State, but at none of these places is it of sufficient thickness or purity to be of value.

California, although rich in many other mineral resources, is singularly deficient in coal. At present the lack of coal is not felt, for the State has abundant supplies of fuel oil, but these supplies will sooner or later be consumed, and when the oil is exhausted the problem of obtaining coal will become vital. The only coal field of any prospective importance is that which lies in the Coast Ranges, in San Benito and Monterey counties, and which is known from the places at which the coal has been prospected. The most ambitious attempt to develop this field was made at Stone Canyon, Monterey County, where a bed of coal ranging from 10 to 14 feet in thickness was opened. The attempt was not successful, however, and the mine was abandoned. This coal is of the bituminous rank, and is the only coal of this rank in the State. It is very rich in bituminous matter and is in composition a cannel coal, though it has none of the physical properties of such a coal.

PRODUCTION AND ORIGINAL TONNAGE OF COAL IN THE UNITED STATES.

Although the general description of a coal field is very important to one considering the development of mines, or to one contemplating an investment in mines or in mineral lands, there is another phase of the subject that is of equal if not greater importance to the political economist, and that is the quantity of coal still remaining in the ground, to which future generations may look for their supply of power and heat. As stated in the first part of this introduction, the United States Geological Survey has endeavored to determine this quantity by making estimates of the original tonnage of the various fields, deducting the coal already mined and wasted in mining, and calling the remainder the present and future supply. Such estimates, when first made, were very unsatisfactory, for the data available, even in some of the coal-mining States of the East, were far from adequate for a quantitative statement of this kind, and some of the western coal fields were so little known that only a guess could be made as to their area or tonnage. Nevertheless an estimate was made and published in 1908, in order to meet some of the demands of the time in the discussion of the available resources of the Nation.

The constantly increasing knowledge of the coal fields of the West acquired by the Geological Survey in the course of its regular work of classifying the withdrawn lands and the interest and activity of several State geologists showed clearly that the first estimate of the United States Geological Survey was inadequate and should be revised at an early date. This revision was undertaken in 1912, and the results of the new estimate were published in 1913 as a part of the report on the coal fields of the world made by the Twelfth International Geological Congress. Though this estimate was founded on much more reliable information, and though this information was much more widely applicable to the coal fields of the country, the writer is still conscious of the weak places that of necessity must exist in such an estimate, and he will relish the opportunity to revise the figures at some future time when new information is available, such as will give the estimate an accuracy that it has not heretofore been possible to attain.

In undertaking to make an estimate of the original tonnage of coal in the ground, certain assumptions must be made as a foundation, and the results attained will depend largely upon these assumptions. The three principal assumptions are (1) minimum thickness of bed of the different ranks and grades of coal that can be mined, (2) maximum depth to which mining may be carried in the different ranks of coal, and (3) maximum percentage of ash that may be permitted in the various ranks of coal. As probably no two persons who have attempted to make estimates have made the same basic assumptions, so no two estimates agree as to the tonnage involved. This point is very important and is one that is usually lost sight of by the casual reader, who doubtless wonders why it is that experts disagree so widely in their estimates; whereas if he had analyzed the results a little more closely he might have found that the results were practically in accord.

Most engineers employed by private corporations base their estimates on the present practice of mining and preparing coal for the market, for the mining company must adopt this practice, and manifestly the company will not consider coal minable if it lies at a depth of 4,000 feet while plenty of coal of the same kind is available at a depth not exceeding 1,000 feet. Similarly, it will not consider minable a coal bed 20 inches thick while other beds of coal of the same kind of much greater thickness are still available. Also, to the operator of the present time, 15 per cent of ash in a coal may prevent its sale, and therefore its mining may be impracticable; whereas, if a washery were installed and plenty of water were available, 15 per cent of ash might be no bar to the mining and marketing of the coal. Most of the estimates so far made have been based on present mining conditions and practices, and hence they do not necessarily represent the tonnage that may be regarded as available 10 or even 5 years hence.

In attempting to make estimates of the original coal content of the fields of the United States, the Geological Survey decided that it would be a waste of time and money to attempt to make estimates based on present mining practice, for such estimates would be misleading in that they would not represent the total quantity of coal that undoubtedly would be made available in the future. With this point in mind, it was decided to attempt to estimate the total quantity of coal that ever would be mined in the United States, looking ahead 40, 50, or perhaps even 100 years. Of course, it is not contended that anyone living to-day can say positively what will be done 100 years hence, but an attempt was made to prepare such a forecast. In doing so the present mining practice throughout the world was considered, and the assumptions regarding maximum depth, minimum thickness, and maximum impurity were based upon present practice, but generally the limits now observed were exceeded because it is almost certain that the future will go far beyond the present operations, for in some places to-day the methods are far better than those that generally prevailed 20 or even 10 years ago.

As the deepest coal mines in the world (in Belgium) reach a depth of about 4,000 feet, and as shafts for copper and other metals have been sunk to depths below 5,000 feet, it was thought that future coal mining might be carried to a depth of 6,000 feet; but in order to meet various requirements two limits were set, one at a depth of 3,000 feet, for easily minable coal, and the other at a depth of 6,000 feet, a depth that represents what is now considered the ultimate limit of coal mining. Similarly the minimum thickness of coal bed mined in the United States is about 15 inches; therefore 14 inches was taken as the minimum of high-rank coals for estimating the original tonnage in the several fields. The minimum thickness varies according to the rank of the coal, being approximately 2 feet in subbituminous coal and 3 feet in lignite. The maximum percentage of ash permissible in a coal is more difficult to determine, on account of the variability of the factors involved in the operation of cleaning such coal for the market. Thirty per cent has been regarded as the limit, but it is questionable whether it would not better be placed at 25 per cent.

With the basic factors of the process determined, the actual application of the principle of estimation is an engineering problem, which depends upon the data collected by the geologist and his mapping of the coal fields. For many of the fields these data are fairly sufficient and reasonably accurate estimates have been made, but for other fields the data are confessedly inadequate and the estimates are correspondingly unsatisfactory. The detailed estimates for the fields and States will be given in the chapters devoted to the States, but the accompanying general table shows the estimates by regions and provinces, as such treatment involves in many of the regions parts of several States and hence can be presented only in this introductory statement.

The table shows clearly certain features that are of the greatest interest regarding the distribution and amount of coal in the fields of the United States. It shows first that the great bulk of the coal in this country is low-rank bituminous, lignite, and subbituminous, named in the order of their abundance, and that the high-rank coals are relatively scarce. This is an important point in conservation, as it means that our best coal will be the first to be exhausted and that such exhaustion may occur in the not very distant future. It is also noticeable that the best steaming coal, the semibituminous, is limited practically to the two eastern provinces, and that the exhaustion of this coal will be a greater calamity to the country than the loss of all the anthracite, for coal of this kind has a greater efficiency and is adapted to more diverse uses than anthracite. Most people think of the eastern part of the United States as the greatest repository of coal in the country, and therefore they may be surprised to find that there are two areas in the West that contain a greater quantity. The greatest quantity of coal originally contained in any single area of continuous coal-bearing rocks is 1,202,032,000,000 tons, in the Fort Union region of Montana, Wyoming, and the Dakotas; the second is 665,660,600,000 tons, in the Green River region of Wyoming; and the third is 550,898,800,000 tons, in the Appalachian region of the East.

When the output of the mines is compared with the original quantity available it is seen that the great bulk of our coal is not necessarily coming from the areas that contain the

Original and present quantity of coal in the United States, production of the mines in 1913 and 1914, and total production from the beginning of coal mining to the present time, in short tons

Province, region, or field.	Estimate of the original tonnage.							Production in 1913.	Production in 1914.	Total production to end of 1914.	Estimated supply within 3,000 feet of surface.
	Anthracite and semianthracite.	Semibituminous coal.	Bituminous coal.	Subbituminous coal.	Lignite.	Total coal of all ranks.	Coal below surface from 3,000 to 6,000 feet.				
Eastern province:											
Anthracite region (Pennsylvania)	21, 000, 000, 000					21, 000, 000, 000		91, 524, 922	90, 821, 507	2, 537, 517, 517	17, 194, 000, 000
Atlantic coast region	150, 000, 000	150, 000, 000	600, 000, 000			900, 000, 000				477, 125	799, 000, 000
Appalachian region		48, 487, 200, 000	502, 411, 600, 000			550, 898, 800, 000		330, 737, 079	284, 813, 462	5, 238, 735, 592	543, 039, 000, 000
	21, 150, 000, 000	48, 637, 200, 000	503, 011, 600, 000			572, 798, 800, 000		422, 262, 001	375, 634, 969	7, 776, 730, 234	561, 032, 000, 000
Interior province:											
Northern and Eastern regions			321, 990, 800, 000			321, 990, 800, 000		88, 533, 841	83, 412, 955	1, 439, 863, 711	319, 830, 000, 000
Western and Southwestern regions	400, 000, 000	1, 226, 300, 000	206, 282, 200, 000			207, 908, 500, 000		26, 694, 136	25, 291, 303	575, 038, 328	208, 044, 000, 000
	400, 000, 000	1, 226, 300, 000	528, 273, 000, 000			529, 899, 300, 000		115, 227, 977	108, 704, 258	2, 014, 902, 039	527, 874, 000, 000
Gulf province					23, 090, 000, 000	23, 090, 000, 000		1, 181, 156	1, 105, 613	10, 509, 960	23, 074, 000, 000
Northern Great Plains province:											
Fort Union region, including Black Hills region			133, 000, 000	237, 475, 000, 000	964, 424, 000, 000	1, 202, 032, 000, 000		2, 149, 254	1, 907, 865	30, 211, 784	1, 201, 997, 000, 000
Small fields in Montana			2, 000, 000, 000	7, 073, 400, 000		9, 073, 400, 000		1, 904, 355	1, 561, 823	24, 907, 259	9, 036, 000, 000
Denver region and Canon City field			1, 028, 000, 000	40, 000, 000, 000		41, 028, 000, 000		2, 340, 654	2, 067, 709	48, 427, 362	40, 955, 000, 000
Raton Mesa region			42, 392, 000, 000			42, 392, 000, 000		8, 194, 362	7, 596, 810	133, 390, 905	42, 192, 000, 000
			45, 553, 000, 000	284, 548, 400, 000	964, 424, 000, 000	1, 294, 525, 400, 000		14, 588, 625	13, 134, 207	236, 937, 310	1, 294, 180, 000, 000
Rocky Mountain province:											
Small fields in Montana			47, 200, 000	3, 496, 000, 000		3, 543, 200, 000		20, 094	20, 000	5, 441, 863	3, 535, 000, 000
Bighorn Basin and Wind River Basin regions, including Red Lodge field			608, 800, 000	4, 706, 700, 000		5, 315, 500, 000	12, 010, 000, 000	1, 604, 524	1, 612, 941	15, 633, 450	5, 291, 000, 000
Green River and Hams Fork regions and Hanna field	22, 600, 000		174, 138, 000, 000	491, 500, 000, 000		665, 660, 600, 000	396, 720, 000, 000	5, 786, 093	5, 377, 756	101, 339, 390	665, 478, 000, 000
Uinta region and Wasatch Plateau	480, 400, 000		162, 768, 000, 000	5, 000, 000, 000		168, 248, 400, 000	243, 540, 000, 000	4, 092, 435	3, 723, 542	57, 317, 183	167, 682, 000, 000
North and South parks			20, 000, 000	2, 850, 000, 000		2, 870, 000, 000				782, 666	2, 870, 000, 000
Southwestern Utah region			4, 000, 000, 000			4, 000, 000, 000			2, 000	2, 000	4, 000, 000, 000
Coalville field, Utah				156, 000, 000		156, 000, 000		108, 027	68, 146	2, 459, 413	152, 000, 000
San Juan Basin region			11, 453, 000, 000	184, 583, 000, 000		196, 036, 000, 000	14, 330, 000, 000	1, 007, 729	874, 332	17, 573, 377	196, 011, 000, 000
Small fields in New Mexico and Arizona			1, 005, 000, 000	20, 891, 000, 000		21, 896, 000, 000		117, 976	137, 361	4, 148, 414	21, 890, 000, 000
Idaho and Nevada fields			600, 000, 000	100, 000, 000		700, 000, 000					700, 000, 000
	503, 000, 000		354, 640, 000, 000	713, 282, 700, 000		1, 068, 425, 700, 000	666, 600, 000, 000	12, 736, 878	11, 816, 078	204, 697, 756	1, 067, 609, 000, 000
Pacific coast province:											
Washington fields			11, 412, 000, 000	52, 442, 900, 000		63, 854, 900, 000		3, 877, 891	3, 064, 820	67, 524, 260	63, 753, 000, 000
Oregon and California fields			27, 000, 000	1, 016, 000, 000		1, 043, 000, 000		[a] 85, 691	[a] 65, 532	[a] 47, 404, 845	1, 032, 000, 000
			11, 439, 000, 000	53, 458, 900, 000		64, 897, 900, 000		3, 963, 582	3, 130, 352	114, 929, 105	64, 785, 000, 000
	22, 053, 000, 000	49, 863, 500, 000	1, 442, 916, 600, 000	987, 514, 000, 000	1, 051, 290, 000, 000	3, 553, 637, 100, 000	666, 600, 000, 000	569, 960, 219	513, 525, 477	[b] 10, 357, 706, 404	3, 538, 554, 000, 000

[a] Includes production of Nevada and Idaho.

[b] A total production of 10,357,706,404 tons is assumed to mean an exhaustion of about 50 per cent more, or 15,083,100,000 tons.

greatest quantity, but from the areas that contain the best coal. This discrepancy becomes more startling when the production of the individual States is compared with their original coal resources.

Although the relative size of the contents of the coal fields may be a matter of some surprise, the really staggering fact presented in the table is the immense, really inconceivable total quantity of the coal. If all the unmined coal within 3,000 feet of the surface, or 3,538,554,000,000 short tons, could be placed in one great cubical pile as solid as it now lies in the ground the pile would be 18 miles long, 18 miles wide, and 18 miles high. Similarly, if all the coal that has been mined in the United States, plus about 50 per cent for waste, a total of 15,083,100,000 short tons, were piled in the same way, the pile would be 1,540 feet long, 1,540 feet wide, and 1,540 feet high; or, in other words, only about 0.4 per cent of the original amount has been mined or wasted in mining.

There has been considerable speculation regarding the length of time the coal supplies would last, but here again there are so many unknown factors that any estimate partakes of the nature of a guess. Figure 2 represents graphically the coal production in the United States by decades since 1834, and the increasing length of black shows conclusively that our coal production, or consumption, as it may well be called, is growing with great rapidity. In attempting, therefore, to calculate how long the available coal will last it is manifestly incorrect to base the calculation on the present rate of production or consumption, or on the rate for the last decade, as the rate will continue to increase for a long time. If we assume that the rate of consumption will remain the same as it was in 1913, then, after allowance has been made for unpreventable waste in mining and marketing, there will be enough coal to last 4,000 years; but of course such an estimate is absurd, for the rate of 1913 will probably not be held in any single future year.

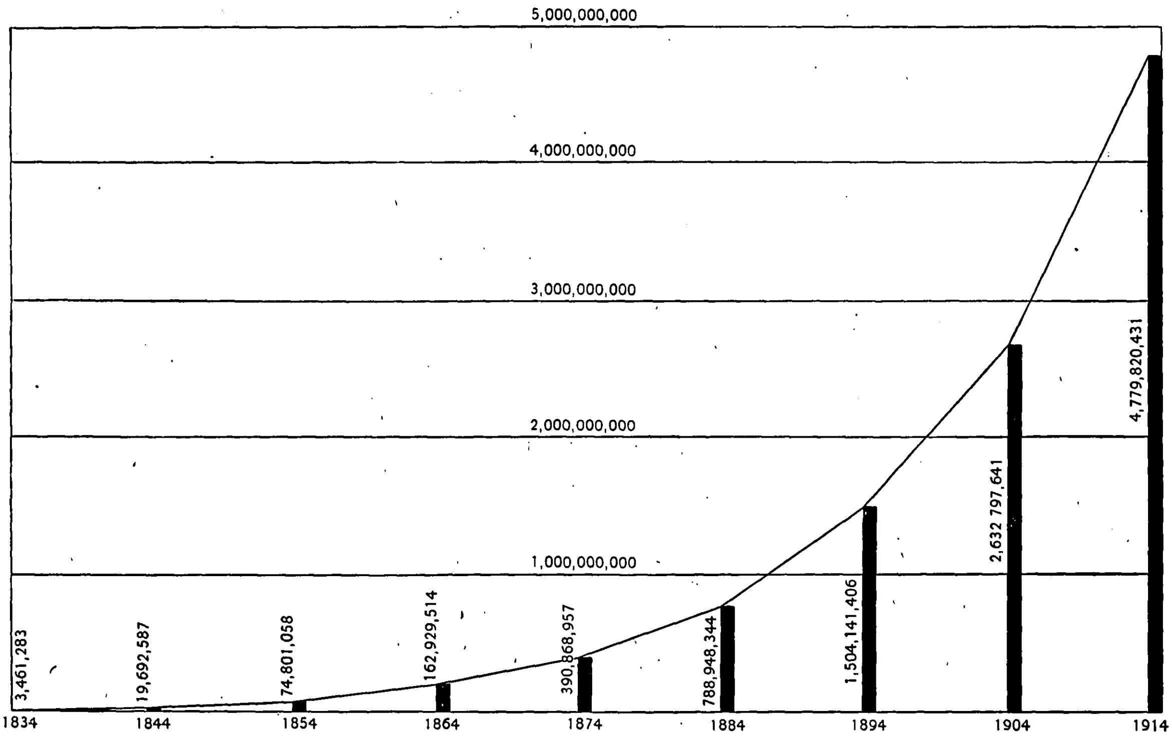

FIGURE 2.—Production of coal in the United States by decades from 1834 to 1914.

If the curve shown in figure 2 should be prolonged at its rapidly increasing rate, and if this acceleration should be continued until the coal is completely exhausted, the supply would probably not last 100 years. The true life of our coal fields probably lies between these two extremes, and the probability is that it will be nearer 100 than 4,000 years.

In 1908 Parker[1] attempted to extend the curve of production to what he conceived might be the possible maximum that would ever be reached in this country. His curve, with slight modification to fit recently acquired data, is shown in figure 3. The past and the estimated future production were grouped by decades, beginning with 1835 and extending to the year 2055, when, according to his calculations, the maximum production of 23,000-000,000 short tons would be reached. As the quantity of coal mined in the decade ending with 1914 was 4,779,820,431 short tons, the maximum, according to Parker's figures, would be roughly five times the present production. After the maximum had been reached the production, owing to increased cost of mine haulage, of hoisting from deeper shafts, and of working thinner beds, would gradually decrease, but the decrease would probably be much less rapid than the increase up to the maximum. According to the present estimates there is enough coal in the ground to permit production at this assumed maximum rate for more than 10 decades or 100 years.

The figures showing the production since 1908 prove that Parker's curve is too flat, for his estimate of the production in the decade ending in 1915 (4,528,000,000 tons[2]) is nearly equaled by the production of the nine years ending with 1914, which is 4,387,097,796 tons. Thus it seems that his estimated maximum production is too small or that the maximum will be reached before the year 2055. The estimate is probably too small and the maximum production will therefore probably be greater than 23,000,000,000 tons in a decade.

Although by every reasonable estimate the ultimate exhaustion of the coal reserves of the United States appears to be an event so far in the future that it need concern this generation but slightly, the fact must be remembered that the bulk of the coal being mined to-day is the best in the country and that before long, perhaps within 50 years, much of the high-rank coal will be exhausted.

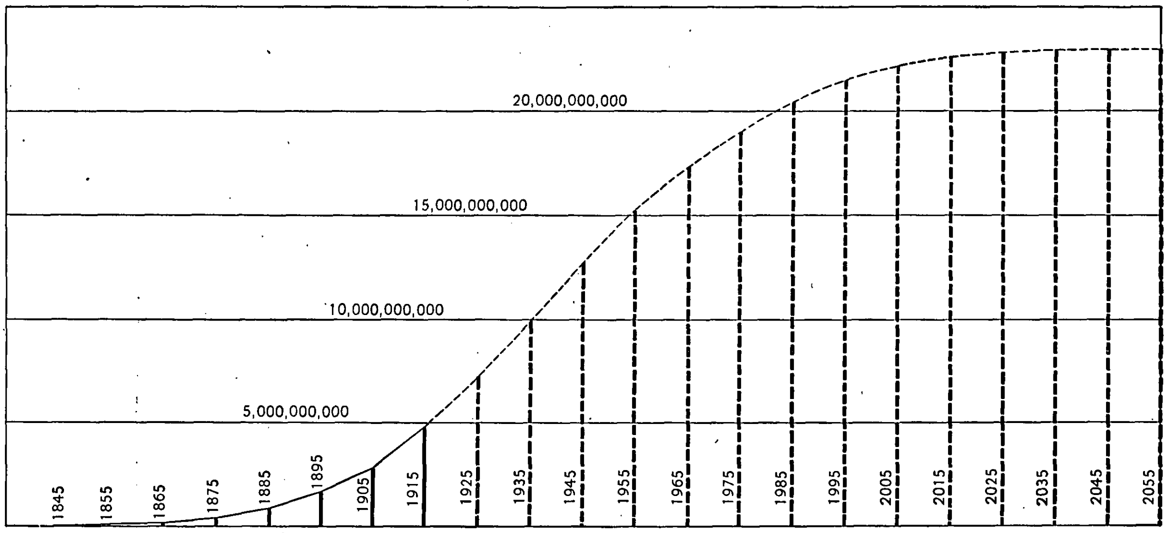

FIGURE 3.—Estimated production of coal in the United States to the year 2055. (After E. W. Parker.)

According to the latest estimates[3] the coal reserves of the world, by continents, are as follows:

	Short tons.
Americas	5, 627, 823, 500, 000
Asia	1, 410, 487, 600, 000
Europe	864, 412, 600, 000
Oceania	187, 842, 900, 000
Africa	63, 755, 900, 000
	8, 154, 322, 500, 000

Of the amount contained in the Americas, the United States claims 4,205,154,000,000 tons, or 51 per cent of the total coal of the world. Listed according to coal reserves, the principal

[1] Parker, E. W., Past and future coal production in the United States: Mines and Minerals, 1908, pp. 462-465.

[2] The production for the decade ending in 1915 was 4,918,717,283 tons.

[3] The coal resources of the world, an inquiry made upon the initiative of the executive committee of the Twelfth International Geological Congress, Canada, 1913, Morang & Co. (Ltd.), Toronto, Canada.

coal-producing countries of the world stand as follows:

	Short tons.
United States, including Alaska	4,231,352,000,000
Canada	1,360,535,000,000
China	1,097,436,000,000
Germany	466,665,000,000
Great Britain and Ireland	208,922,000,000
Siberia	191,667,000,000
Australia	182,510,000,000
India	87,083,000,000
Russia in Europe	66,255,000,000
Union of South Africa	61,949,000,000
Austria	59,387,000,000
Colombia	29,762,000,000
Indo-China	22,048,000,000
France	19,382,000,000
Other countries	69,369,500,000
	8,154,322,500,000

ANALYSES OF REPRESENTATIVE COALS.

In order that the reader may obtain an idea of the comparative value and rank of the coals of the United States, analyses of representative samples are tabulated on the following pages. The figures given are those obtained by the analysis of individual samples of coal, but each sample has been so selected that it represents the average composition of the coal of a certain district or field or the composition of a certain rank of coal.

Most of the analyses given in the table were made by the Bureau of Mines or the United States Geological Survey and so are strictly comparable, but for a few coals, as indicated, such analyses are not available and the figures given are taken from a State report.

The analysis given is that of the sample of coal as it was received at the laboratory. This sample was sealed in an air-tight receptacle immediately after it was cut in the mine, and it reached the laboratory in the same condition as it was in when it was cut in the mine. For this reason the analyses show a larger percentage of moisture than most analyses made for private persons, because the samples so analyzed have not been sealed and the coal has therefore lost some of the moisture it contained when it was in the mine. The Government analyses represent the coal as it leaves the mine and approximately as it reaches the consumer. If the coal is shipped in dry and hot weather some of its moisture may be evaporated; on the other hand, if rain falls on the coal in transit, its original moisture content may be appreciably increased.

The analyses are as follows:

Analyses of representative coals of the United States.

[Unless otherwise specified all analyses were made by the United States Geological Survey or the Bureau of Mines.]

Location and rank of coal.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Heat value (British thermal units).
ALABAMA.						
Lookout Mountain, semibituminous	3.8	19.0	64.4	12.8	1.5	12,980
Blount County, bituminous	3.4	27.7	55.9	13.0	1.2	12,740
Birmingham district, bituminous, coking	2.4	25.9	66.8	4.9	1.5	14,490
Do	2.3	29.7	58.0	10.0	.8	13,490
Birmingham district, bituminous	2.6	31.8	62.9	2.7	.8	14,630
Carbon Hill district, bituminous	4.7	31.8	53.3	10.2	1.3	12,600
Tuscaloosa district, bituminous	1.6	25.0	68.5	4.9	.5	14,700
Cahaba field, bituminous	3.1	35.0	55.8	6.1	.4	13,560
Do	3.2	31.0	59.6	6.2	1.2	14,140
ARIZONA.						
Black Mesa field, subbituminous	9.9	32.6	46.9	10.6	1.1	10,800
ARKANSAS.						
Russellville district, semianthracite	2.1	9.8	78.8	9.3	1.7	13,700
Spadra district, semianthracite	1.7	10.5	79.5	8.3	2.5	13,870
Coal Hill district, semibituminous	1.4	14.8	76.9	6.9	1.5	14,330
Paris district, semibituminous	2.8	14.7	73.4	9.1	2.8	13,770
Jenny Lind district, semibituminous	1.6	17.4	73.1	7.9	1.4	14,160
Huntington district, semibituminous	3.5	16.7	72.0	7.8	1.3	14,020
Camden district, lignite	39.4	26.5	24.4	9.7	.5	6,360

Analyses of representative coals of the United States—Continued.

Location and rank of coal.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Heat value (British thermal units).
CALIFORNIA.						
Stone Canyon district, bituminous	7.0	46.7	40.1	6.2	4.2	12,450
Mount Diablo district, subbituminous	15.0	38.4	34.5	12.1	5.6	9,240
Tesla district, subbituminous	18.0	39.2	26.4	16.4	3.1	8,110
COLORADO.						
Denver field, subbituminous	18.8	30.5	44.5	6.2	.3	9,650
Do	25.6	28.0	41.1	5.3	.4	9,180
Colorado Springs field, subbituminous	26.2	29.7	37.7	6.4	.3	8,350
Canon City field, bituminous	9.1	35.7	48.0	7.2	.9	11,700
Trinidad field, bituminous, coking	2.3	29.8	58.7	9.2	.5	13,780
Trinidad field, bituminous, noncoking	7.8	38.5	44.8	8.9	.5	11,540
North Park field, subbituminous	20.0	32.5	42.5	5.0	.6	9,750
Yampa field, anthracite	7.0	3.4	75.6	14.0	.6	11,740
Yampa field, bituminous	10.4	37.9	45.5	6.2	.4	11,470
Newcastle field, bituminous	7.1	40.8	46.9	5.2	.5	12,620
Newcastle field, bituminous, coking	2.9	33.3	56.7	7.1	.5	13,720
Coal Basin field, semibituminous	2.4	19.4	70.8	7.4	.5	14,380
Crested Butte field, anthracite	3.0	2.9	86.6	7.5	.7	13,500
Crested Butte field, bituminous	5.6	37.6	47.6	9.2	.4	12,430
Grand Junction field, bituminous	7.6	33.6	52.9	5.9	.7	12,440
Durango field, bituminous, coking	2.7	36.1	54.5	6.7	.5	13,910
GEORGIA.						
Manlo district, semibituminous	2.9	17.1	72.2	7.8	.7	14,200
IDAHO.						
St. Anthony field, bituminous	11.5	37.2	47.0	4.3	.5	12,090
Goose Creek field, lignite	34.3	26.6	25.7	13.4	2.5	8,610
ILLINOIS.						
La Salle County, bituminous	13.9	37.3	38.5	10.3	3.4	10,990
Peoria County, bituminous	15.5	34.7	39.8	10.0	2.9	10,740
Fulton County, bituminous	15.7	31.4	43.1	9.8	3.0	10,620
McLean County, bituminous	10.2	35.9	40.1	13.8	2.8	11,150
Logan County, bituminous	14.8	32.9	39.7	12.6	4.0	10,410
Sangamon County, bituminous	14.3	37.2	40.3	8.2	4.4	11,010
Macoupin County, bituminous	13.3	37.1	40.7	8.9	4.1	11,160
Montgomery County, bituminous	12.7	35.5	40.2	11.6	4.2	10,670
Madison and St. Clair counties, bituminous	12.7	36.4	41.4	9.5	3.7	10,990
Marion County, bituminous	10.3	37.4	39.8	12.5	3.7	11,080
Franklin County, bituminous	9.2	33.8	48.6	8.4	.9	11,930
Williamson County, bituminous	8.8	29.9	53.8	7.5	1.1	12,220
Saline County, bituminous	6.0	32.4	54.3	7.3	1.7	12,790
Gallatin County, bituminous	3.4	35.2	52.5	8.9	2.9	13,190
INDIANA.						
Vermilion County, bituminous	10.5	39.5	39.6	10.4	4.0	11,430
Clay County, bituminous, block	15.4	32.6	46.1	5.9	2.0	11,680
Sullivan County, bituminous	13.6	35.0	44.6	6.8	1.1	11,550
Knox County, bituminous	10.6	38.1	43.0	8.3	3.7	11,750
Pike County, bituminous	11.3	38.3	43.5	6.9	3.1	11,920
Warrick County, bituminous	10.4	39.2	42.0	8.4	3.5	11,820
Vandenburgh County, bituminous	9.7	35.6	44.5	10.2	2.9	11,440
IOWA.						
Boone County, bituminous [a]	19.5	33.4	38.3	8.8	5.4	10,520
Polk County, bituminous	14.4	37.8	36.8	11.0	5.9	10,640
Jasper County, bituminous [a]	9.3	39.2	39.1	12.4	2.4	11,210
Marion County, bituminous	15.7	36.9	35.8	11.6	5.1	10,290
Mahaska County, bituminous [a]	14.6	36.3	40.5	8.6	2.9	11,000

[a] Analyses made by the Iowa State University.

Analyses of representative coals of the United States—Continued.

Location and rank of coal.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Heat value (British thermal units).
IOWA—continued.						
Lucas County, bituminous	18.7	31.8	41.8	7.7	2.4	10,510
Monroe County, bituminous	15.8	36.9	37.9	9.4	4.7	12,900
Wapello County, bituminous	11.3	38.7	39.5	10.5	4.7	11,350
Taylor County, bituminous [a]	20.2	30.1	38.3	11.4	4.2	10,120
Appanoose County, bituminous	17.1	35.4	40.4	7.1	4.0	10,930
KANSAS.						
Leavenworth County, bituminous	12.0	35.2	39.1	13.7	4.4	10,720
Linn County, bituminous	11.1	28.8	47.5	12.6	2.4	11,220
Crawford County, bituminous	4.9	33.5	52.5	9.1	5.0	12,940
Cherokee County, bituminous	5.1	32.6	53.4	8.9	4.3	12,930
EASTERN KENTUCKY.						
Johnson County, bituminous	6.4	36.2	54.1	3.3	1.2	13,460
Johnson County, bituminous, cannel	2.2	50.6	36.7	10.5	1.0	13,750
Pike County, bituminous	2.8	36.2	56.7	4.3	1.4	14,180
Letcher County, bituminous	2.5	36.5	57.0	4.0	.6	14,150
Perry County, bituminous	3.9	37.2	54.8	4.1	.8	13,730
Laurel County, bituminous	4.5	39.9	50.8	4.8	2.3	13,510
Harlan County, bituminous	4.4	35.0	56.9	3.7	.7	13,920
Bell County, bituminous	2.8	37.8	56.3	3.1	1.0	14,240
Knox County, bituminous	4.2	36.4	53.3	6.1	.8	13,410
WESTERN KENTUCKY.						
Daviess County, bituminous	11.8	36.8	42.0	9.4	3.3	11,150
Ohio County, bituminous	10.0	36.5	44.9	8.6	2.6	11,770
Muhlenberg County, bituminous	8.8	36.2	46.4	8.6	3.6	11,900
Hopkins County, bituminous	8.5	38.0	46.4	7.1	3.5	12,340
Union County, bituminous	3.9	37.1	49.7	9.3	3.5	12,830
MARYLAND.[b]						
Georges Creek basin, semibituminous, high rank	.6	16.6	72.1	10.7	1.3	13,380
Georges Creek basin, semibituminous, medium rank	.6	17.7	73.0	8.7	1.4	14,010
Georges Creek basin, semibituminous, low rank	.7	20.3	70.0	9.0	1.4	14,010
Upper Potomac basin, semibituminous	.9	18.1	71.9	9.1	1.7	14,010
Upper Potomac basin, semibituminous	1.7	19.0	68.1	11.2	1.6	13,450
Castleman basin, semibituminous	2.1	22.0	67.1	8.8	2.3	13,870
Castleman basin, bituminous	.7	24.0	66.8	8.5	1.4	13,970
Upper Youghiogheny basin, bituminous	1.2	23.0	63.9	11.9	2.1	13,260
Lower Youghiogheny basin, bituminous	2.3	25.5	64.4	7.8	1.1	13,780
MICHIGAN.						
Saginaw district, bituminous	11.9	31.5	49.8	6.8	1.2	11,780
MISSOURI.						
Putnam County, bituminous	18.5	32.6	39.0	9.9	4.1	10,040
Harrison County, bituminous	15.3	37.1	40.8	6.8	3.0	10,100
Adair County, bituminous	15.4	34.8	38.8	11.0	3.6	10,460
Grundy County, bituminous	11.7	38.8	38.8	10.7	5.1	11,020
Macon County, bituminous	13.8	34.7	41.8	9.7	3.3	10,960
Randolph County, bituminous	12.1	36.3	42.9	8.7	3.9	11,450
Audrain County, bituminous	10.4	39.3	38.0	12.3	4.9	11,350
Ray County, bituminous	15.8	32.8	41.5	9.9	3.0	10,620
Lafayette County, bituminous	12.3	34.4	42.0	11.3	4.6	11,000
Henry County, bituminous	10.6	37.2	40.7	11.5	3.6	11,250
Bates County, bituminous	7.8	35.5	44.0	12.7	5.2	11,740
Vernon County, bituminous	6.5	32.6	50.8	10.1	5.0	12,460
Barton County, bituminous	5.4	32.1	53.6	8.9	3.6	12,990

[a] Analysis made by the Iowa State University.
[b] Analyses made by the Maryland Geological Survey. Each analysis is the average of all analyses of a certain coal bed in that basin or field.

Analyses of representative coals of the United States—Continued.

Location and rank of coal.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Heat value (British thermal units).
MONTANA.						
Culbertson district, lignite	40.8	25.2	27.8	6.2	0.7	6,150
Glendive district, lignite	34.6	35.3	22.9	7.2	1.1	7,090
Miles City district, subbituminous (?)	29.2	26.2	35.4	9.2	.8	7,670
Havre district, subbituminous	25.6	27.9	39.2	7.3	.6	8,290
Cutbank district, bituminous	6.6	40.3	39.2	13.9	3.1	10,930
Lewistown district, bituminous	8.0	26.6	56.1	9.3	4.4	11,510
Sand Coulee district, bituminous	6.0	28.4	51.4	14.2	2.4	11,150
Roundup district, subbituminous	13.4	32.4	47.6	6.6	.4	11,120
Bridger district, bituminous	9.8	27.6	46.2	16.4	.6	10,240
Bear Creek district, subbituminous	10.7	34.1	46.1	9.1	1.5	10,800
Red Lodge district, subbituminous	11.7	36.1	40.2	12.0	1.1	9,790
Trail Creek field, bituminous	12.4	36.8	42.3	8.5	.6	10,950
Electric field, bituminous, coking	4.0	22.5	59.3	14.2	.6	12,760
Missoula field, lignite	24.7	29.3	26.1	19.9	.9	6,730
NEVADA.						
Esmeralda County, bituminous	2.1	33.7	33.7	30.5	7.2	9,590
NEW MEXICO.						
Raton field, bituminous, coking	2.1	36.1	50.2	11.6	.6	12,970
Los Cerrillos field, anthracite	5.7	2.2	86.1	6.0	.7	13,270
Los Cerrillos field, bituminous	3.2	41.4	44.4	11.0	1.6	12,450
Carthage field, bituminous, coking	3.0	38.0	51.6	7.4	.9	13,260
White Oaks field, bituminous	2.5	37.9	44.9	14.7	.8	12,260
Monero district, bituminous, coking	3.0	39.0	48.3	9.7	3.5	12,930
Gallup district, subbituminous	12.7	36.5	43.3	7.5	.7	11,230
NORTH DAKOTA.						
Ward County, lignite [a]	36.5	28.4	28.7	6.4	1.4	6,750
Mountrail County, lignite [a]	37.8	30.1	24.3	7.8	.6	6,230
Williams County, lignite	41.1	27.2	26.3	5.4	.7	6,490
Northern McLean County, lignite [a]	40.0	29.7	27.1	3.2	.3	6,610
Southern McLean County, lignite	40.5	27.1	27.4	5.0	.8	6,640
Morton County, lignite	38.5	27.6	26.6	7.3	1.3	6,700
Stark County, lignite [a]	40.5	26.3	27.0	6.2	.8	6,210
Billings County, lignite [a]	37.0	26.3	28.7	8.0	1.8	6,590
Adams County, lignite	32.4	30.9	28.1	8.6	1.5	7,330
Bowman County, lignite	41.4	23.9	28.4	6.3	.7	6,240
OHIO.						
Stark County, bituminous [b]	6.7	36.2	48.9	8.2	2.7	12,560
Tuscarawas County, bituminous [b]	4.7	39.2	49.9	6.2	3.3	12,770
Jefferson County, bituminous	4.1	38.5	49.7	7.7	3.7	13,150
Coshocton County, bituminous [b]	4.5	38.7	50.8	6.0	3.6	12,910
Belmont County, bituminous	3.9	43.1	43.9	9.1	4.4	12,840
Guernsey County, bituminous	6.0	34.2	52.0	7.8	2.0	12,720
Noble County, bituminous	3.6	41.5	44.4	10.5	4.9	12,510
Perry County, bituminous [b]	6.7	37.1	49.1	7.1	2.6	12,390
Washington County, bituminous [b]	3.4	37.9	49.1	9.6	5.0	12,750
Hocking County, bituminous [b]	7.5	34.0	52.6	5.9	.8	12,510
Meigs County, bituminous [b]	7.2	32.8	50.7	9.3	1.3	12,000
Jackson County, bituminous [b]	5.3	41.0	45.3	8.4	3.7	12,210
Lawrence County, bituminous	7.1	33.7	50.3	8.9	1.3	12,090
OKLAHOMA.						
Craig County, bituminous	4.1	37.4	48.3	10.2	6.1	12,920
Rogers County, bituminous	4.2	38.2	47.8	9.8	5.2	13,910
Tulsa County, bituminous	6.3	37.7	47.8	8.2	8.2	12,690
Okmulgee County, bituminous	7.5	32.9	51.0	8.6	1.5	12,410
Haskell County, semibituminous	2.7	21.1	69.9	6.3	.8	14,100
Le Flore County, semibituminous	3.1	31.7	58.9	6.3	.9	14,020
Latimer County, bituminous	3.0	36.0	55.9	5.1	1.1	13,710
Pittsburg County, bituminous	3.6	33.4	58.0	5.0	.5	13,740
Coal County, bituminous	6.5	39.0	45.2	9.3	3.7	11,840

[a] Analyses made by North Dakota Geological Survey.

[b] Analyses made by the Ohio Geological Survey.

Analyses of representative coals of the United States—Continued.

Location and rank of coal.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Heat value (British thermal units).
OREGON.						
Coos Bay field, subbituminous	18.0	31.8	39.7	10.5	2.2	8,910
Eden Ridge field, bituminous	12.6	35.0	37.7	14.7	1.3	10,350
PENNSYLVANIA.						
Anthracite region, anthracite	2.8	1.2	88.2	7.8	.9	13,300
Do	2.2	5.7	86.2	5.9	.6	13,830
Sullivan County, semianthracite	3.4	9.3	75.6	11.7	.8	13,120
Tioga County, semibituminous	2.3	20.9	66.9	9.9	1.3	13,620
Elk County, bituminous	2.7	33.7	54.9	8.7	2.9	13,470
Center County, semibituminous	2.9	19.9	69.7	7.5	1.9	14,080
Center County, bituminous	3.5	23.7	61.6	11.2	2.7	13,060
Clearfield County, semibituminous	3.3	19.9	69.0	7.8	2.0	14,020
Clearfield County, bituminous	2.8	24.3	66.3	6.6	.9	14,130
Indiana County, bituminous	1.0	26.1	63.8	9.1	2.7	13,950
Butler County, bituminous	4.6	33.0	54.4	8.0	1.3	13,200
Cambria County, semibituminous, high rank	3.3	12.5	77.9	6.3	1.0	14,340
Cambria County, semibituminous, low rank	2.0	21.2	70.9	5.9	1.2	14,510
Cambria County, bituminous	3.1	26.0	64.4	6.5	1.4	14,160
Westmoreland County, bituminous, coking	2.7	30.4	57.8	9.1	1.3	13,610
Allegheny County, bituminous	3.7	34.0	56.8	5.5	1.4	13,870
Broadtop field, semibituminous	2.1	15.5	76.0	6.4	1.1	14,470
Somerset County, semibituminous, high rank	2.5	12.5	78.8	6.2	1.1	14,380
Somerset County, semibituminous, low rank	2.6	21.5	68.0	7.9	1.7	13,900
Fayette County, bituminous, coking	2.8	30.0	59.8	7.4	1.2	13,990
Washington County, bituminous	1.4	34.6	57.8	6.2	.8	14,240
RHODE ISLAND.						
Portsmouth district, anthracite	13.2	2.6	65.3	18.9	.3	9,310
SOUTH DAKOTA.						
Harding County, lignite	41.5	24.0	24.3	10.2	.6	5,650
TENNESSEE.						
Claiborne and Campbell counties, bituminous	3.6	37.3	55.5	3.6	1.1	13,980
Scott and Fentress counties, bituminous	3.8	38.5	51.2	6.5	1.9	13,400
Anderson County, bituminous	2.2	37.2	54.5	6.1	1.6	13,960
Morgan County, bituminous	2.0	37.5	52.6	7.9	4.0	13,810
Roane and Rhea counties, bituminous, coking	2.2	29.6	59.4	8.8	.5	13,620
Cumberland County, bituminous	4.3	25.7	62.5	7.5	.6	13,630
Overton County, bituminous	3.4	35.6	50.6	10.4	3.1	12,990
White County, bituminous	3.0	39.7	46.9	10.4	4.1	13,950
Hamilton County, bituminous	2.9	29.9	59.2	8.0	1.2	13,760
Bledsoe and Sequatchie counties, bituminous	3.0	29.8	58.9	8.3	1.0	13,560
Grundy County, bituminous	3.6	29.8	57.9	8.7	1.4	13,330
Marion County, bituminous	3.4	28.2	60.1	8.3	.8	13,430
TEXAS.						
Houston County, lignite	33.5	39.5	16.2	10.8	.6	7,140
Wood County, lignite	28.9	35.9	27.3	7.9	.5	8,000
Milam County, lignite	36.0	27.9	28.7	7.4	.8	7,130
UTAH.						
Summit County, subbituminous	14.2	36.0	44.8	5.0	1.4	10,630
Uinta County, bituminous	8.6	36.1	47.2	8.1	1.4	11,580
Grand County, bituminous	7.1	37.0	45.4	10.5	.7	11,720
Carbon County, bituminous	4.4	38.2	50.5	6.9	.8	12,760
Emery County, bituminous	7.2	42.2	44.8	5.8	.7	12,540
Iron and Kane counties, anthracite	8.2	4.4	58.0	29.4	2.3	8,910
Iron and Kane counties, semibituminous	9.5	13.2	49.2	28.1	3.6	8,860
Iron and Kane counties, bituminous	10.4	36.3	43.7	9.6	5.8	10,870

Analyses of representative coals of the United States—Continued.

Location and rank of coal.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Heat value (British thermal units).
VIRGINIA.						
Appalachian region:						
Tazewell County, semibituminous	3. 8	15. 5	77. 8	2. 9	0. 6	14, 860
Buchanan County, semibituminous	2. 4	19. 6	64. 6	13. 4	. 7	13, 160
Buchanan County, bituminous	3. 5	31. 9	60. 9	3. 7	1. 5	14, 390
Dickinson County, bituminous	3. 0	32. 4	58. 4	6. 2	1. 6	14, 030
Russell County, bituminous	2. 8	34. 9	56. 5	5. 8	. 6	14, 150
Wise County, bituminous, coking	2. 5	31. 7	60. 3	5. 5	. 5	14, 250
Lee County, bituminous	3. 4	34. 4	58. 8	3. 4	. 6	14, 130
Montgomery County, semibituminous	1. 6	12. 3	68. 1	18. 0	. 5	12, 340
Richmond Basin, bituminous	2. 8	25. 7	62. 5	9. 0	1. 4	13, 490
WASHINGTON.						
Whatcom County, anthracite	4. 4	7. 4	76. 0	12. 2	1. 0	12, 590
King County:						
Newcastle district, subbituminous	12. 1	36. 8	40. 7	10. 4	. 3	10, 410
Grand Ridge district, subbituminous	15. 9	36. 0	38. 5	9. 6	. 5	9, 970
Snoqualmie district, bituminous	6. 1	22. 7	58. 8	12. 4	. 9	10, 710
Renton district, subbituminous	14. 4	36. 1	42. 0	7. 5	. 6	10, 560
Taylor district, bituminous	5. 6	35. 9	44. 1	14. 4	. 9	11, 550
Ravensdale district, bituminous	7. 4	37. 4	43. 9	11. 3	. 5	11, 500
Black Diamond district, bituminous	6. 8	40. 0	47. 9	5. 3	1. 4	12, 330
Bayne district, bituminous	4. 1	32. 8	52. 8	10. 3	. 5	12, 780
Pierce County:						
Burnett district, bituminous	3. 2	35. 0	49. 3	12. 5	. 4	12, 720
Gale Creek district, bituminous	2. 8	33. 8	53. 9	9. 5	1. 0	13, 450
Wilkeson district, bituminous, coking	2. 5	27. 7	61. 3	8. 5	. 4	13, 890
Wilkeson district, semibituminous	3. 6	19. 1	61. 3	16. 0	. 5	12, 320
Carbon Hill district, bituminous	3. 4	32. 2	49. 5	14. 9	. 5	12, 250
Fairfax district, bituminous	3. 6	23. 6	59. 3	13. 5	. 4	12, 750
Fairfax district, semibituminous	4. 0	18. 1	58. 5	19. 4	. 5	11, 820
Fairfax district, semianthracite	9. 2	9. 4	63. 7	17. 7	. 7	11, 130
Kittitas County:						
Beekman district, bituminous	3. 3	34. 1	50. 5	12. 1	. 4	12, 910
Roslyn district, bituminous	4. 7	36. 0	46. 8	12. 5	. 4	12, 240
Cle Elum district, bituminous	5. 0	36. 1	46. 8	12. 1	. 4	11, 900
Thurston County:						
Centralia district, subbituminous	21. 0	33. 1	36. 7	9. 2	. 4	8, 910
WEST VIRGINIA.						
Wheeling district, bituminous	4. 1	36. 6	53. 3	6. 0	2. 1	13, 400
Moundsville district, bituminous	3. 4	41. 6	48. 0	7. 0	3. 3	13, 310
Fairmont district, bituminous	2. 9	34. 5	56. 9	5. 7	. 7	14, 040
Clarksburg district, bituminous	2. 8	38. 5	53. 1	5. 6	2. 4	14, 110
Upper Potomac basin, semibituminous, high rank	1. 1	17. 2	73. 8	7. 9	1. 1	14, 490
Upper Potomac basin, semibituminous, low rank	1. 2	20. 4	70. 8	7. 6	1. 0	14, 520
Preston County, bituminous	3. 6	27. 4	62. 8	6. 2	. 9	14, 220
Buckhannon district, bituminous	2. 5	32. 5	56. 3	8. 7	1. 7	13, 590
Sutton district, bituminous [a]	2. 3	38. 3	52. 9	6. 5	2. 1	13, 530
Clay district, bituminous	2. 8	35. 5	54. 7	7. 0	. 8	13, 700
Winfield district, bituminous	5. 0	39. 6	48. 3	7. 1	1. 8	13, 000
New River field:						
New River district, semibituminous, high rank	4. 0	14. 1	73. 7	8. 2	. 8	13, 850
New River district, semibituminous, low rank	3. 5	22. 2	71. 9	2. 4	. 7	14, 690
Beckley district, semibituminous, high rank	4. 7	13. 0	77. 9	4. 4	. 8	14, 340
Beckley district, semibituminous, low rank	3. 3	18. 0	75. 6	3. 1	. 8	14, 660
Montgomery district, bituminous	2. 4	35. 5	56. 7	5. 4	1. 0	14, 160
Coalburg district, bituminous	3. 4	35. 2	53. 1	8. 3	. 7	13, 300
Logan district, bituminous	3. 3	33. 3	58. 4	5. 0	. 7	14, 050
Thacker district, bituminous, high rank	3. 1	31. 4	59. 9	5. 6	1. 2	14, 050
Thacker district, bituminous, low rank	4. 5	38. 8	50. 9	5. 8	2. 0	13, 370
Iaeger district, semibituminous	2. 0	19. 9	70. 4	7. 7	. 7	14, 110
Pocahontas field, semibituminous, low rank	3. 4	22. 5	68. 8	5. 3	. 5	14, 370
Widemouth district, semibituminous, medium rank	3. 1	18. 2	74. 8	3. 9	. 7	14, 690
Welch district, semibituminous, high rank	2. 8	12. 5	80. 4	4. 3	. 7	14, 660

[a] Analysis by West Virginia Geological Survey.

Analyses of representative coal of the United States—Continued.

Location and rank of coal.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Heat value (British thermal units).
WYOMING.						
Sheridan district, subbituminous	22.6	32.5	40.4	4.5	0.3	9,220
Bighorn Basin field, subbituminous	16.5	32.9	45.8	4.8	.6	10,750
Black Hills region, bituminous, coking	10.0	39.1	34.3	16.6	4.9	10,250
Glenrock district, subbituminous	21.9	34.0	37.4	6.7	.9	9,070
Hudson district, subbituminous	21.1	31.4	41.7	5.8	.5	9,460
Hanna Basin field, subbituminous	11.5	42.6	39.3	6.6	.4	10,890
Rock Springs field, bituminous	9.8	34.3	52.5	3.4	1.0	12,260
Kemmerer district, bituminous	5.7	37.7	51.3	5.3	1.4	12,580
Kemmerer district, subbituminous	20.6	36.3	40.5	2.6	.5	10,240
Evanston district, subbituminous	14.4	36.8	41.6	7.2	.2	10,440

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