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THE VALUATION OF PUBLIC COAL LANDS

THE VALUE OF COAL LAND

BY

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DEPTH AND MINIMUM THICKNESS OF BEDS AS LIMITING FACTORS IN VALUATION

BY

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CONTENTS.

THE VALUE OF COAL LAND.

By GEORGE H. ASHLEY.

INTRODUCTION.

LAWS RELATING TO THE SALE OF COAL LANDS.

The laws of the United States relating to the sale of coal lands, as contained in the Revised Statutes, read as follows:

SEC. 2347. Every person above the age of twenty-one years, who is a citizen of the United States, or who has declared his intention to become such, or any association of persons severally qualified as above, shall, upon application to the register of the proper land office, have the right to enter, by legal subdivisions, any quantity of vacant coal lands of the United States not otherwise appropriated or reserved by competent authority not exceeding one hundred and sixty acres to such individual person, or three hundred and twenty acres to such association, upon payment to the receiver of not less than ten dollars per acre for such lands where the same shall be situated more than fifteen miles from any completed railroad, and not less than twenty dollars per acre for such lands as shall be within fifteen miles of such road.

SEC. 2348. Any person or association of persons severally qualified, as above provided, who have opened and improved, or shall hereafter open and improve, any coal mine or mines upon the public lands, and shall be in actual possession of the same, shall be entitled to a preference right of entry, under the preceding section, of the mines so opened and improved: *Provided*, That when any association of not less than four persons, severally qualified as above provided, shall have expended not less than five thousand dollars in working and improving any such mine or mines, such association may enter not exceeding six hundred and forty acres, including such mining improvements.

SEC. 2349. All claims under the preceding section must be presented to the register of the proper land district within sixty days after the date of actual possession and the commencement of improvements on the land, by the filing of a declaratory statement therefor; but when the township plat is not on file at the date of such improvement, filing must be made within sixty days from the receipt of such plat at the district office; and where the improvements shall have been made prior to the expiration of three months from the third day of March, eighteen hundred and seventy-three, sixty days from the expiration of such three months shall be allowed for the filing of a declaratory statement, and no sale under the provisions of this section shall be allowed until the expiration of six months from the third day of March, eighteen hundred and seventy-three.

SEC. 2350. The three preceding sections shall be held to authorize only one entry by the same person or association of persons; and no association of persons any member of which shall have taken the benefit of such sections, either as an individual or as a member of any other association, shall enter or hold any other lands under the provisions thereof; and no member of any association which shall have taken the benefit

of such sections shall enter or hold any other lands under their provisions; and all persons claiming under section twenty-three hundred and forty-eight shall be required to prove their respective rights and pay for the lands filed upon within one year from the time prescribed for filing their respective claims; and upon failure to file the proper notice, or pay for the land within the required period, the same shall be subject to entry by any other qualified applicant.

SEC. 2351. In case of conflicting claims upon coal lands where the improvements shall be commenced, after the third day of March, eighteen hundred and seventy-three, priority of possession and improvement, followed by proper filing and continued good faith, shall determine the preference right to purchase. And also where improvements have already been made prior to the third day of March, eighteen hundred and seventy-three, division of the land claimed may be made by legal subdivisions, to include, as near as may be, the valuable improvements of the respective parties. The Commissioner of the General Land Office is authorized to issue all needful rules and regulations for carrying into effect the provisions of this and the four preceding sections.

SEC. 2352. Nothing in the five preceding sections shall be construed to destroy or impair any rights which may have attached prior to the third day of March, eighteen hundred and seventy-three, or to authorize the sale of lands valuable for mines of gold, silver, or copper.

AREAS OF COAL LANDS CLASSIFIED.

Prior to July, 1906, it was the practice to dispose of coal lands at the minimum prices fixed by the law, viz, $20 per acre for lands within 15 miles of a completed railroad and $10 per acre for lands beyond the 15-mile limit. Since that date lands which have been classified and valued have been disposed of at fixed prices based upon the value of the coal contained in the land. July 26, 1906, large areas known or supposed to contain coal were withdrawn from entry and this withdrawal was followed by others. At the same time the Geological Survey began an appraisement of these withdrawn lands, which were returned to entry as rapidly as they were classified and appraised. The following table shows approximately the areas withdrawn for classification and those classified and restored on November 1, 1909.

Areas withdrawn for classification and classified and restored, in acres.

State.	Withdrawn from coal entry pending examination and classification.	Withdrawn from all entry pending classification—field work completed.	Classified and restored November 1, 1909.
Wyoming	5,475,990	6,056,656	10,205,803
Washington	2,291,320	.....	612,440
Utah	4,638,080	207,360	1,728,000
Oregon	386,561	.....	885,120
Montana	9,295,360	1,082,880	8,075,300
New Mexico	3,283,420	864,000	5,122,560
Colorado	5,856,320	3,651,680	4,755,120
South Dakota	.....	.....	2,169,917
North Dakota	645,120	.....	2,360,995
Total	31,872,171	11,862,576	35,915,255

At the time this policy was established the Geological Survey had examined only a very small part of the coal fields in the public-land States. From that time, however, the examination of coal lands was rapidly extended and the work of classification and valuation was increased until it became necessary, in order to unify and correlate the work, to create a board of three members, who should prepare or revise all of the classifications made.

One of the first acts of this board was to collect additional data on the value and workability of coals and to review carefully the former basis of classification. As a result of this review, recommendations for a new and somewhat more definite basis of classification and valuation were presented to the Secretary of the Interior and resulted in the "Regulations on the classification and valuation of coal lands," approved by the Secretary of the Interior April 10, 1909. Under these new regulations classifications have been made as follows, from April 10 to October 31:

	Acres.
Classified as coal land	2,533,562
Classified as noncoal land	10,291,822
Restored without classification	493,003
Total acted on	13,318,387
Sale price of coal land as fixed	$141,890,576
Sale price of same coal land at minimum would be	47,080,040
Gain in seven months (Apr. 10 to Oct. 1)	94,810,536

OBJECT OF PRESENT PAPER.

The object of this paper is to present briefly some of the facts on which the Department's regulations for classifying and valuing coal lands are based. The information already at hand in the Survey has been supplemented by data obtained in the fall of 1909 by the writer in Colorado, Wyoming, and Utah, concerning the values of coal lands in those States.[a] In dealing with the financial side of the question it has been necessary or desirable to group some of the data and to omit names of authorities. It is not pretended that the discussion is exhaustive or complete, but it is believed that the facts selected are representative and that the conclusions based upon them would be confirmed rather than upset by the presentation of additional information.

The data are not evenly distributed or of equal value, being meager as to some districts and very full as to others.

[a] The writer, who is a member of the Survey's land-classification board, has for many years given special attention to the economics of coal. One of his earliest reports on this subject, bearing the title "The finances of coal," was published in 1899 (Twenty-third Ann. Rept. Indiana Dept. Geology and Natural Resources, pp. 1490–1517).

ROYALTY VALUE OF COAL LAND.

SOURCE OF VALUE OF COAL LAND.

Coal land derives its value from the coal that underlies it, and the value of coal, like that of every other commodity, is in a broad way determined by the supply and demand, which fix the sale price of coal in open market. On the one hand is the seller, demanding a price that will pay him for the expense of mining, preparing, and transporting the coal, and leave him a satisfactory profit; on the other hand is the buyer, seeking the cheapest market and willing to pay only such price as will yield him a satisfactory return either in comfort or in financial benefit for service rendered or manufactured goods prepared.

Coal is a commodity for which the supply and demand are both large and widespread, and active competition among both sellers and buyers tends to produce a more or less stable balance, the selling price differing from place to place chiefly because of difference in the cost of transportation. As transportation facilities improve and multiply, this stable balance comes into more nearly perfect equilibrium from point to point, except as it may be temporarily affected by widespread strikes, car shortage, or general changes in economic conditions.

PRICES OF COAL.

The selling price of coal may be taken at the mine, as it is with large contracts, or it may be determined by subtracting transportation and storage charges and losses and middlemen's profits from the sale price at the point of consumption, the result being the sale price at the mine. For the sake of uniformity the sale price may be assumed to be always f. o. b. at the mine.

In a purely theoretical study it might be possible to estimate the value of the coal in the ground by computing its heat-giving value, either actual or potential, as applied to serve human need and demand, and the total available supply. As this paper is, however, a study of actual conditions and of the value of coal under those conditions, the study must start from the sale price at the mine.

The sale price of coal at the mine may be divided roughly into three elements:

1. Cost of coal in ground.
2. Cost of removing from ground and preparing for market.
3. Profit.

The cost of the coal in the ground appears in one of two ways, either in the purchase of all of the beds or of a single bed of coal below a given number of acres of the surface, with or without the surface itself, or by purchase of the coal ton by ton as it is mined, under a leasehold contract with the owner.

The cost of removing the coal from the ground and preparing it includes all the costs of equipment, labor, materials, interest, marketing, amortization (or the laying aside of a fund for the replacement of the plant when worn out), and a fund to meet accidents and contingencies. These costs make up a more or less nearly definite figure or "fixed charge" for any locality, which is subject to change with change of conditions, but in general forms an item of expense that must be met if operations are to continue.

The profit, if any, is the difference between the costs stated above and the price the seller may be able to obtain for his coal.

The purchase of the coal in the ground for mining at some future time usually involves the cost of carrying the coal—in interest and taxes—to the time of mining, allowances for uncertainties as to the amount and quality of coal underlying the acreage purchased, and many other unknown factors. On the other hand, payment for the coal ton by ton as it is brought out of the ground eliminates these elements of uncertainty. It has therefore been uniformly recognized that the royalty rate at which coal is paid for per ton at any chosen place is the truest measure of what it is there worth commercially in the ground.

Here, again, supply and demand, in a broad way, determine the royalty rate. Where, as in the Illinois coal field, a score of million acres of coal land are awaiting development and the present demand is exhausting only a few thousand acres a year, the owner of the coal may be willing to part with it for almost nothing rather than to see it lie and yield him nothing at all. Under these conditions he may lease the coal for a price as low as 2 cents a ton. On the other hand, where the supply is small and the demand great—as in the Connellsville coking field of Pennsylvania, the anthracite field of Pennsylvania, or in some fields in the West—the royalty may be from 40 cents to $1 a ton. The price last mentioned is local. In a general way, in the bituminous coal fields outside of the Connellsville coking field royalties on large contracts range from 5 cents to 15 cents, the average being not far from 10 cents a ton.

ROYALTIES NOW PAID.

The following table shows the royalties now paid in many eastern and western coal fields. The table gives the royalty in cents; the minimum yearly royalty, where that is at hand; and the bonus on the lease, where such bonus is paid. Although the figures may be lacking for some districts, a minimum royalty is practically everywhere exacted. A bonus is, however, paid less frequently. A minimum royalty is fixed to encourage production up to at least a certain amount, with the penalty of having to pay for that amount whether it is produced or not; and as the courts have declared that such a mini-

mum royalty is payable each year, it serves to encourage continuous operation. The bonus is a cash payment, and as a rule is exacted only where conditions are especially favorable. Under a lease on developed property the bonus may cover the cost of improvement; otherwise the bonus must be considered as so much addition to the royalty. Under some leases the bonus is rated at so many cents a ton; it is then simply an addition to the royalty. Under other leases it is a cash payment, demanded when the lease is made, and becomes a diminishing charge per ton against the coal as the output increases.

Royalties paid in some coal districts of the United States.

Locality.	Royalty, in cents.	Minimum yearly royalty.	Bonus on lease.
Pennsylvania:			
Anthracite fields	Up to 50		
Clearfield district	5–15	$1,000 per 100 acres	None.
Connellsville district—			
Coal	16–20		
Coke	24–30		
Pittsburg district	10–15		
Ohio:			
Massillon district	[a] 10–15		1 to 8 cents per ton.
Hocking Valley district	8		
West Virginia:			
Fairmont district	6	$600 to $300,000	None.
Pocahontas district—			
Coal	10–15	$12.50 an acre to $45,000	$25 an acre to $200,000.
Coke	15–24		
Kanawha district	5½–10	$10 an acre to $20,000	$25 an acre.
New River district	10	$10 an acre	Do.
Kentucky:			
Northeastern Kentucky district	8–12	$300 to $500	None.
Southeastern Kentucky district	10–11		
Western Kentucky district	3		$100 to $500 a year.
Tennessee:			
Jellico district	10		None.
Alabama:			
Walker County district	7–10	Amount equivalent to taxes on land.	
Jefferson County district	7–12½	$100	
Indiana:			
Vigo County district	3		
Greene County district	[a] 4–10	$100 to $200	None.
Evansville district	2–3⅛		
Illinois:			
La Salle district	[a] 10–25		$15 to $50 an acre.
North Illinois district	5		
South Illinois district	2		
Arkansas	3		
Oklahoma	8		
Colorado:			
State lands	10	$100 to $500 (?)	
Boulder County district	8–27½		
Trinidad district	8–12½	Up to $20,000	
Routt County district	8–10		
Wyoming:			
Wyoming State lands	3–6		
Southwestern Wyoming	10		
Small local mines	Up to 100		
Indian reservations	8–10		
Utah:			
Small mines	Up to 75		
Montana:			
Miles City district	15		
Roundup district	15		

[a] Royalty computed on screened coal; in other districts royalty is computed on run-of-mine coal.

The foregoing table has been compiled partly by correspondence with officers of some of the largest coal companies in the districts named, partly by personal inquiry, and partly from published reports on new leases at the time they were made.

The data are not complete, even for the districts cited. Some of the figures are based on general statements of representative operators as to the conditions in the field; others are based on royalties paid by one or more mining companies. Each royalty is computed on mine-run coal, except those marked *a*, whose basis is screened coal.

In fixing the rate no account is generally taken of differences in the thickness and quality of the coal. Thus, in Colorado the royalties charged in the Trinidad field for high-grade coking coal are not observably different from those paid in the Boulder field for relatively low-grade subbituminous coal, or "black lignite." The Boulder County field, however, by its proximity to Denver, has an advantage that offsets the lower grade of the coal. Nevertheless, it remains true that, except perhaps in the Connellsville coking coal and Pocahontas coal fields, little or no correspondence can be found between the royalty rates and the quality of the coal. In eastern Kentucky, it is said, the rate is affected by the thickness of the bed. Thus, beds running from 3 to 4 feet pay 8 cents; from 4 to 5 feet, 10 cents; from 5 to 6 feet, 12 cents. In Wyoming the rate charged for coal mined on State lands depends on the amount of coal mined yearly, being 6 cents a ton for all coal mined and sold up to 25,000 tons, 5 cents a ton between 25,000 and 50,000 tons, 4 cents a ton between 50,000 and 100,000 tons, and 3 cents a ton on over 100,000 tons. In Colorado the state lands containing coal are leased on a straight 10-cent royalty.

As will be seen from the table, royalties in the eastern interior coal fields of Illinois, Indiana, and western Kentucky are extremely low. The coal beds are regular and abundant and so widespread that nearly every farm in an area of 40,000 to 50,000 square miles is underlain by workable coal. Under these conditions, with a network of railroads running everywhere, the prospective operator has an almost unlimited field from which to choose and may practically dictate his own terms. On the other hand, in local areas in parts of the West competition is lacking or restricted, so that the operator has practically a free hand as to the price he may ask for his coal in the market; he can pay whatever royalty is demanded by the owner of the coal and still get a good profit, even though, as sometimes happens under these conditions, he pay a royalty of from 25 cents to $1 a ton. As a rule mines in such areas are not commercial mines in the usual sense, although some of them that are near towns may yield a considerable output. Under special conditions

a few large commercial mines have paid a royalty as high as 27½ cents a ton.

The Appalachian coal field is favorably situated as to markets, much of the coal is of high grade, and the coal land has been in large measure absorbed by mining companies, but because of the rugged topography of the country, railroad construction has been slow, and a relatively small part of the area is accessible for immediate mining. Furthermore, the coal in different parts of the field differs greatly in quality, particularly when considered with reference to its adaptability to special uses, such as coking. Accordingly, there is in this field a better balance between the buyer and the seller of coal lands, and much higher royalties are paid here than farther west in the Mississippi Valley.

Royalties paid in the East show a decided tendency to advance. Thus, in the Pocahontas district of West Virginia the royalty has long been 10 cents a ton for coal and 15 cents a ton for coke. Recent leases, however, call for a royalty of at least 15 cents a ton on coal and 24 cents a ton on coke, with a large cash bonus and a high minimum royalty. In Alabama ten years or more ago royalties were 5 cents a ton; to-day they range from 7 to 12½ cents, with a strong tendency toward the higher figure. The advance is seen also in the widespread change in the mode of measurement—from lump coal to mine run—without change or corresponding decrease in the royalty. Formerly nearly all of the royalties paid in Colorado were computed on screened coal; to-day royalties, with few exceptions, are computed on mine-run coal. In general it will be found that where the figures given in the table show a range in royalty the contracts recently made give the higher rate. This tendency of the royalty to rise is seen in still another way—in the frequent requirement of a bonus, which may be only the entering wedge for an increase in the royalty. As conditions change so as to favor the lessor he is in a position to demand better terms for a lease. Where the royalty rate has been long established it may be difficult to raise it, so that an easier method of getting higher prices is to ask a bonus. This bonus may be increased until the lessee finds it to his advantage to ask for a higher royalty without the bonus. If this device is kept in view the fact will be recognized that where a bonus is asked, as shown in the table on page 10, the royalty should be assumed to be a little higher than that given under the heading "Royalty."

ROYALTIES AND LAND PRICES.

What will an acre of coal land yield on a royalty? A bed of bituminous coal 1 acre in extent and 1 foot thick contains approximately 1,750 tons of coal. Under the best conditions of mining it should yield over 1,500 net tons. As a rule mining will not recover over

1,300 tons, and under some conditions mining does not actually net over 1,000 tons per acre-foot. Under the best conditions an acre of coal 1 foot thick will yield, at a royalty rate of 10 cents a ton, $150 gross; under the worst conditions it will yield $100. If the last figure be taken, an acre of bituminous coal 5 feet thick should yield $500 gross income; an acre containing a 10-foot bed or two 5-foot beds should yield $1,000. At 20 cents a ton the gross income from royalty would be twice those figures.

Royalties in the Connellsville coking district are quoted at from 16 to 20 cents. The Pittsburg bed there averages about 7 feet thick, and at 20 cents a ton the land in this district should yield in gross royalties from $1,400 to $2,100 an acre. It is of interest to note in this connection that $1,700 to $2,000 an acre has recently been paid in this field for coal lands. Some of these lands will not be mined out for twenty years to come, and the average duration of many contracts is ten years or more. The compound interest on $1,700 at 5 per cent for ten years, with taxes at $1.50 per $100, would bring the cost of the land at the time it is worked out to more than $3,000 an acre, or about double the gross income from royalties at the rate quoted. It must be at once evident that no leases are being made to-day at these rates—the rates quoted are for old contracts or for existing contracts made years ago. They are of interest, however, as illustrating the possibility that the actual sale price of coal land may be more than the gross royalty value under existing contracts.

Selling prices of coal land that are equivalent to the royalty value are rare, though under exceptional conditions they are sometimes found. For example, a coal company in Colorado had mined up to a certain 40 acres, and the coal in the area mined out had run very regularly 5 feet thick. Computed on a net recovery of 1,000 tons per acre at 10 cents a ton this 40 acres had a royalty value of $100 per acre-foot, or $500 per acre, and it is reported that the land was purchased at that price. It was evident that the time for mining out the coal purchased would be small, so that interest charges would amount to but little.

In general, however, the sale price of coal land must necessarily be less than the gross royalty income that the same land would bring at the prevailing royalties. In the first place, the net royalty income derived by the lessor may be quite different from the gross income. There is the cost of collection, and possibly of inspection, which may amount to 5 to 10 per cent or more of the gross income. In the second place, the operator who buys his coal land rather than leases it must pay interest and taxes on it from the time of the purchase until the coal has been mined out. These should be computed on the average length of time each acre is carried. If mining is started immediately after purchase and is continued regularly

for twenty years, the average time of carrying the coal will be ten years. The first cost of the land may be increased one-half to three times or more, the increase depending on the rate of interest, so that a tract of land bought for $100 an acre may have actually cost $150 to $300 or more an acre by the time the coal is mined. In other words, an acre of land that, when mined ten years hence, would yield $500 in royalties would be worth to-day, if interest is 5 per cent and taxes are left out of account, $314; with interest at 7 per cent it would be worth today $253; at 10 per cent only $108. Taxes would still further decrease these amounts. If twenty years be taken as the life of the average active mine, the first acre of coal will be mined out the first year, the last acre the twentieth year, and the average acre in ten years. On a tract of land, therefore, that, it is confidently estimated, will be mined out within twenty years the purchase value can hardly be more than one-half the estimated royalty value. If that value be again cut in half on the possibility that the estimated tonnage may be too large, the buyer is made doubly secure; and a still further reduction from one-fourth to one-fifth the estimated royalty value, such as is made on the highest government valuations, is just that much more in favor of the buyer.

It may therefore be confidently said that where the conditions are favorable to the almost immediate development of a piece of coal land, its purchase value may be estimated at from one-fifth to one-half its estimated royalty value. The estimated royalty value may differ from the actual royalty value by as much as the estimated amount of coal in the land differs from the actual amount. Exceptionally the estimate may be larger than the actual value, but as a rule, since the estimate must be made on only a part of the facts, it will fall below the real value.

FAIRNESS OF GOVERNMENT PRICES.

The prices now being placed on the government coal lands, as explained on pages 37–45, represent one-fifth of the computed royalty value, an ultra-conservative estimate which in turn is based on a conservative estimate that only 1,000 tons per acre-foot of the coal computed to be in the ground can be recovered. This estimate applies only to lands containing but a single workable coal bed. For lands containing more than one coal bed a reduction in price is made on the additional beds. Thus, the price of the second bed may be only one-eighth of its estimated royalty value; that of the third bed only one twelfth; and the prices of all other beds may be estimated at only one-sixteenth of the royalty value, to allow for the delay that must usually ensue before the second, third, and other less valuable beds are worked. In general the government price for lands containing several beds will average not far from one-tenth of the estimated royalty value.

Moreover, this relation of the government prices to the estimated royalty value is maintained only as to the high-grade, noncoking bituminous coals; for coals of lower grade the minimum price is only one-fortieth of the royalty value, as determined by the royalties now charged for low-grade coals in the same general region. Royalties in the West tend to remain uniform, regardless of the variety of the coal (anthracites possibly excepted), but the government prices are scaled down rapidly as the grade of the coal becomes lower, partly to encourage the mining of the lower-grade coals, partly because of their lower calorific value and their greater tendency to break down on weathering.

The private owner of coal lands must consider his ownership as an investment, and the interest on that investment must be charged against the value of the land. It is therefore an even thing to him whether he sell the land at its present value as determined by the royalty or hold it and realize on the royalties when the coal is mined. The rate of interest to be paid for carrying the land is assumed to be the same whether the interest is paid by the purchaser or the lessor. In the government prices the rate of interest computed has been liberal, averaging as high as 7 per cent, with an average time of recovery of the coal of ten years, equal to a total length of life of the mine of twenty years. As the Government is paying only 3 per cent for money, it is giving the purchaser the benefit of the difference. Still more important, as the estimated royalty value is always based on partial information, the purchaser always getting the benefit of the doubt, the government price, plus interest at 3 per cent, may be only a small fraction of the actual royalty value, the difference, less the cost of collection and inspection, being the Government's loss. The government estimates for the coal in some districts may be too high—even so high as to overbalance the difference between the selling price and the royalty value. An intimate knowledge of government valuations placed on coal lands, however, convinces the writer that overvaluations will be few. Their possible existence is only another argument for the fairness of the lease system as contrasted with the practice of selling the coal land.

FACTORS AFFECTING THE SALE PRICE OF COAL LAND.

GENERAL NATURE OF THE FACTORS.

Among the factors affecting the price of coal land are the character and amount of the coal, competition, knowledge of coal content, accessibility, cost of mining and marketing, demand, and artificial and legal restrictions. Each of these factors in turn is composed of many elements. Their effect on the price of coal lands varies greatly with time, place, and circumstance, as may be seen by examining the selling prices of coal lands at various times and places as recorded, for

example, in the mining journals. Thus the same company operating over a wide territory may on the same day buy land equally rich in coal for 50 cents an acre in one place and for $500 an acre in another. Lands containing coals of the highest grade may have little or no present market value if they are entirely inaccessible or if some element of cost prohibits mining—such as the increase of cost due to the absence of water. At some time in the future the lands may be made accessible by the building of a railroad, or the element prohibiting profitable mining may be overcome, when the lands at once acquire full normal value as determined by the other factors. It may be that the overcoming of the nullifying factors places no burden on the land, as is the case when a railroad is built by disinterested parties.

It may be well to illustrate briefly the effect of some of these factors on the present market price of coal.

QUALITY OR CHARACTER OF COAL.

Other things being equal, the sale price of coal should be directly proportional to its quality and character. But in the first place, quality and character differ along several lines and have different values as the coal is applied to different uses, so that it is not possible to arrange all coals in a column in the order of their quality and character. And in the second place, the cost of different coals is so nearly equal that either a high-grade coal must sell at a large profit in order that a low-grade coal may bring any profit, or, as is generally the case, the high-grade coal must sell at only a reasonable or a small profit and the low-grade coal must remain in the ground because it can not be profitably sold.

Until recently it has been the general rule that all of the coals entering a single market were treated as of one grade, or, for larger markets, as of four or five grades. Thus, all southern Illinois coals in the Chicago market would be regarded as a single class and sold at the same rate. But with the increasing use of the B. t. u. method of selling coal—that is, the sale of coal at prices determined by the number of British thermal units of heat it will yield—it has become necessary to discriminate between coals procured from different mines of the same company and between coal from different parts of the same mine, and slight differences of quality may make differences in demand and price. This mode of rating the value of coal naturally affects the price of coal lands. Areas which produce coal that is up to required standards are enhanced in value, and neighboring areas which formerly competed with them on even terms, but whose coal falls a little below that standard, are depressed in value. The increasing discrimination of coal buyers will tend to increase the difference in price that is due to slight difference of quality. This discrimination will work to the advantage of the higher-grade coals and to the disadvantage of the lower-grade coals, cutting down the sales and

profits on the latter and making it necessary for operators on coals of low grade to seek new markets or new uses, or to be satisfied with smaller profits, or to stop mining.

When, in place of the slight differences between coals from neighboring mines, the buyer considers the greater differences between coals from different parts of the same field, or from different fields, or the difference in value between coals of entirely distinct classes, the effect on prices will be still more marked if the competing coals have to pay equal transportation charges. Fortunately, however, for the lower-grade coals, they can frequently find a local market where the advantage in the freight rates over the higher-grade coals allows them to compete with profit. In this case the price of the land is not affected by a difference in the quality of the coal, for the difference is balanced by an opposite difference in transportation charges.

The differences in coal include not only differences in calorific value, as measured in British thermal units, but differences in the amount of impurities, in hardness, in liability to weathering, and in other features. Every factor that affects the coal's transportability or that requires the use and handling of a larger amount of fuel, such as the handling of waste, affects its price in the market and, unless offset by some advantages, tends to lower the value of the land from which the coal came.

The variations in the price of coal lands produced by slight differences in the character of the coal they contain are well illustrated in the Pittsburg field of southwestern Pennsylvania. In a small part of that field the coal from the Pittsburg bed will produce a high-grade coke that is of great value in the metallurgy of iron. Adjoining parts of the same bed, by reason of the presence in the coal of 1 or 2 per cent more of sulphur or for other causes, will not produce coke of so high grade. The land containing the coal that will produce the high-grade coke may sell for $1,500 to $2,000 per acre. Adjacent lands that contain coal which will not produce such coke, though the coal is equally thick, may sell for only $50 to $150 per acre. A comparison of the selling prices of anthracite and bituminous coal lands may show still greater differences.

Now, suppose that a cheap process be discovered for satisfactorily removing the sulphur of the sulphurous Pittsburg coal or of otherwise rendering it capable of producing a high-grade coke; instantly the value of the land containing such coal will increase, though not perhaps to the former value of the land containing the regular coking coal, for the increase in the supply would probably produce a slump in the price of that coal.

In a district that is fully supplied with a high-grade coal a coal of slightly lower grade may not find a market or may not be mined at a profit, for the lower-grade coal will sell only at a lower rate, and if,

as is often the case, it costs as much to mine the low-grade coal as the other, the margin of profit may be too small to allow any cutting in price. In such a district the lands containing coal of lower grade have little or no market value.

The partial exhaustion of the higher-grade coal in the district, however, or the increased cost of mining that coal, due to mining at a greater depth or to other causes, may advance the selling price of the high-grade coal in the market to a point at which it becomes possible to mine the low-grade coal (which has remained untouched) with as much profit as that obtained on the high-grade coal. Then land containing this easily available low-grade coal becomes worth as much as land containing the less accessible higher-grade coals.

QUANTITY OF COAL.

The quantity of coal underlying a tract of land may not affect the selling price of the land so strikingly as the quality or character of the coal. If, of two areas tested, one contains a coal bed averaging 4 feet thick, and the other a bed of similar coal 6 feet thick, in general the latter land will not sell for one-half more than the former. This discrimination is in part due to the fact that the thickness of any coal bed is more or less variable from place to place, and experience has shown that the average thickness found in mining is likely to differ somewhat from the average determined by the most thorough prospecting. Again, as much coal may be taken out of a 3-foot bed by long-wall mining as may be taken from a 4-foot or 5-foot bed by other methods of mining.

For mining a thin coal bed (a bed less than 3 feet thick, say) miners usually demand a higher rate of pay, the rate increasing as the thickness of the coal decreases, and they refuse to mine at all any bed below a certain thickness. On a thin bed, therefore, the increased cost of mining may destroy all profit, so that coal below a certain thickness can not be profitably mined, and if the whole bed is of that thickness or less it is classed as not workable and the land is considered valueless as coal land so far as that bed is concerned.

The term "nonworkable on account of thinness" is, however, a relative term, for a bed that is too thin to work to-day may with changed conditions be worked at a profit ten years or fifty years hence. Two concrete examples will illustrate this point:

1. The reputation of Clearfield coal was established on coal obtained from the Moshannon bed, in Clearfield County, Pa. The coal in the mines in the sixties and seventies averaged over 5 feet thick. The coal was so abundant that parts of the bed that were less than 5 feet thick or that contained coal a little below the standard grade were passed by as unminable. To-day a host of small mines are recovering those passed-by pieces, and much of the new mining is done in a split of the Moshannon bed that is only 2½ feet thick.

2. In 1897 the writer mapped large areas south of Brazil, Ind., which were dotted over with the dump heaps of old mines that had worked out the Upper Block coal. The Lower Block coal in the same areas had proved unworkable. In 1908 the same areas were dotted with new slack piles, telling of the complete mining out of the Lower Block coal. The changed conditions in eleven years had made it possible to mine out the Lower Block with profit.

The same story can be repeated from a large number of the older coal fields, and it is therefore evident that, within certain limits, coal beds so thin that they can not be profitably mined to-day have a prospective value, which may be roughly estimated at their value when mined, less the cost of carrying to that time.

In the pioneer stages of buying coal lands, when the price is but a few dollars an acre, little or no account may be taken of the quantity of coal underlying a tract of land—that is, land containing two or three workable beds will sell for the same price as land containing only one bed. As a rule it is conjectural how much coal there may be under these lands. As prospecting and development reveal more and more the actual or probable quantity of coal under a tract of land, and as prices approach more nearly actual market values, the true volume of coal is more and more taken into account in determining the value of the land. But in fields where mining has long shown a general regularity in the thickness of a bed—such as the Pittsburg bed or certain beds in the Illinois-Indiana field or in the Canon City field of Colorado—the price of the land may vary from place to place with variations in the thickness of the bed, the price being estimated by the acre-foot of coal, or at so much per acre for each foot of coal, by estimated thickness.

Where there are several beds on the same land it is the general practice to work only one bed at a time, if one or more of the beds are better or thicker than the others. The unworked beds must then be carried while better beds are being worked. If all of the beds are paid for at the same price, the carrying of these unworked beds imposes a burden on the bed that is worked. In order to avoid this burden it is usual to put a low value on all but the best bed, the deduction being greatest for the beds likely to be worked last.

Where the beds are of nearly equal workability it is not uncommon to work two or three beds on the same tract at the same time, as in the Appalachian coal field, where the beds outcrop at different levels on hill slopes. A concrete example of this is seen in the mines on Bennetts Fork, in the Middlesboro district of Kentucky, where the beds worked are several hundred feet apart and separate inclines are used for each level.[a] In Indiana at many places shaft

[a] Prof. Paper U. S. Geol. Survey No. 49, 1906, Pl. I, etc.

mining is done on two or three beds on the same land at the same time. Most of these beds are less than 100 feet apart (two of them are only 30 feet apart), and separate shafts, or "twin shafts," are used to raise the coal from the different levels, or a shaft or slope is driven to the lower bed and the coal of the upper bed is let down by means of a drop shaft or an interbed slope. Two beds that dip may be mined from a single opening by a rock crosscut driven from one bed to the other, as in the Big Four mine, Huerfano County, Colo., where two beds, 4 and 7 feet thick and 60 feet apart, are thus worked.

If two or more beds fairly close together are worked at the same time, peculiar devices must be employed, such as that of leaving a heavy block of coal in the lower bed under the entries in the upper bed, so that the plan of giving a reduced value to the second, third, and other beds, in order of workability, may well apply whether the beds be worked successively or at the same time.

Where there is more than one bed, another factor must be considered—the effect of mining the thick lower bed on the mining of overlying thinner beds later. If the beds are mined successively, from the top downward, little difficulty is encountered, except from the accumulation of water in the old workings of the mine above; but where the first bed to be worked is not the uppermost bed, the settling of the roof may disturb the lay of the beds above and possibly render some of them unworkable. It is obvious that the effect on the overlying coal will vary with the thickness of the underlying bed, the distance between the beds, the character of the intermediate rocks, and the method of mining.

In the Clearfield district of Pennsylvania the Moshannon bed, a 5-foot bed, is overlain at about 35 feet by the "Cap" bed, 3 to 4 feet thick. The intervening rocks are mainly shales and sandstones in varying proportion. Mr. Cameron, superintendent of the Berwin-White mines in that district, reports that recent attempts to mine the "Cap" bed in the area where the Moshannon bed had been mined had found the upper bed but little disturbed, or not at all, certainly not enough to interfere seriously with its mining. On the other hand, Mr. Davis, of the Evanston land office, states that, to his personal knowledge, the mining out of a 12-foot bed disturbed the rocks to a point 250 feet above the bed, solid rock being found only at that height. A similar disturbance of the roof, produced by the destruction of underlying coal beds, is seen in the areas of burned-out coal that are so abundant throughout the West. In general, it would seem safe to assume that the working out of a lower bed will not seriously disturb a bed that lies at a distance above it equal to more than twenty times its thickness. In many places coal beds one-half that distance above a mined bed will not be seriously broken up.

The value of the thick beds of the West, ranging from 50 to 80 feet, is still problematic. Beds up to 15 feet thick are successfully worked. Robert Forrester states that it should be possible to get 80 to 90 per cent of the coal from a 14-foot bed. From beds above that thickness the percentage of recovery with present mining practice is likely to fall rapidly with increase in the thickness of the beds until, with beds from 30 to 80 feet thick, the recovery may drop down to 25 per cent, or the bed prove to be unworkable by present methods. Numerous attempts to work beds over 30 feet thick have had to be abandoned. In some of the western mines on thick coal—as in the Colorado Fuel and Iron Company's mine at Newcastle—it has been impossible to keep out fire. On the other hand, in the anthracite region of Pennsylvania and in European countries thick coals are successfully mined, the method being to mine out a part of the coal, fill in the area excavated so as to support the roof, then mine out the rest of the coal. In its details the method varies greatly, but the general principle involved is the same. Where the strata are more or less inclined, dirt or slack may be flushed in as in the anthracite field. It has been suggested [a] that in some places the workings could be properly planned and the flushing done through unlined bore holes, such as are used for oil wells.

In a mine in Scotland, where the conditions are peculiar, a 30-foot bed can be completely mined out. [b] The coal is underlain by a very soft clay, and as fast as the bottom 5 feet of the bed are mined the clay rises and fills the space vacated, making a new floor on which another 5 feet can be taken, and so on until the whole bed has been recovered.

Nevertheless, the fact remains that while there can be no doubt as to the workability of the beds of the Western States, with a high percentage of recovery from most of them, they can not be so worked to-day with financial success in competition with other coals. Where it is necessary to fix the price on a thick bed for immediate sale and mining, the writer would suggest that it be considered as a multiple bed; that is, that the first 15 feet of it be considered as a first bed, carrying full value; that the next 15 feet be considered a second bed and valued accordingly; that the third 15 feet be considered a third bed, etc.

COMPETITION.

That competition affects the value of coal land is obvious. The term "competition" as here used means not only competition between mines, but competition between transportation companies and buying and selling agencies. Without competition the coal may be worth as high as $1 a ton in the ground, and royalties as high

[a] Parker, E. W. (oral communication). [b] Forrester, Robert (oral communication.)

as $1 a ton are being paid in the West under those conditions. Without competition the difference between the selling price at the mine and the cost of production in some places in the West is over $1. Obviously were such conditions to continue in any large area until the beds had been completely worked out the land would have a value of over $1,000 per acre foot, less the cost of carrying it. In one area in Utah the difference between the cost of mining and the selling price was $1.15. In another it was estimated to be $1.25. Suppose the future profit of mining at the first place be reduced to $1 a ton. The coal being mined is 22 feet thick, of which 14 feet are obtained, a recovery equal, at the conservative estimate of 1,000 tons per acre-foot, to an output of 14,000 tons per acre, selling for $14,000 more than the cost of mining. The land was originally purchased from the Government at $20 an acre. It has therefore yielded an income (aside from the interest on $20) of $13,980. Suppose that an acre of such land were purchased January 1, 1910, and mined out within a year. It is evident that $13,000 an acre might be paid for it and yet the investment might yield 15 per cent. Of course such conditions are rare and uncertain of continuance. The example given, however, shows that where competition is lacking or is controlled an acre of land just ahead of an active mine will yield a good return on a seemingly abnormally high purchase price. It is usually impossible to purchase a tract so small that it will not take several years to mine it out, and the interest and taxes on the land for the average number of years the coal is carried, together with the uncertainty that present conditions will continue, tend to reduce an apparently safe purchase price 50 to 75 per cent or more.

The preceding example may be looked at in another way. The lessor is actually receiving a royalty of 75 cents a ton, the other 40 cents being the profit of the operator. If such a tract of land, under lease at such a royalty, be mined out in twenty years and yield 14,000 tons per acre, what would it be worth to the owner at the beginning of the twenty years at a price that will yield 10 per cent interest on the investment, compounded annually, with taxes at 1 per cent of the purchase value? If X equals the purchase price, then—

$$X = \frac{14{,}000 \times \$0.75}{1\,(1.10^{10} + 20 \times 0.01)} = \$3{,}684.$$

Interest is computed for the average time the coal is carried, or ten years. This gives $3,684 as the purchase price that the lessor might pay and get 10 per cent on his investment, if only the items of interest and taxes be considered.

Were the royalty only 10 cents a ton, as doubtless it would be if competition were open, the same land, in the same time, would yield the lessor 10 per cent on an investment or purchase price of

$491 per acre, if the purchase covered only this one bed. Actually there are three beds under the land. These two prices, however, show clearly the possible difference in value in the West between land in one place where there is competition and in another where there is none. This land was purchased from the Government for $20 an acre.

In the Middle West or Mississippi Valley fields, where the great development of coal-carrying railroads and the policy of making low ton-mile rates for long hauls has resulted in excessive competition, royalties have been forced still lower (from 2 cents to 5 cents a ton), and correspondingly lower prices have been paid for the coal land. George S. Rice [a] cites lands in Illinois containing two workable beds, 6 feet and 8 feet thick, which sold for $10 an acre. If only 50 per cent of the coal can be mined these beds should yield 13,000 tons, or, at $10 an acre, one-thirteenth of a cent a ton. The coal is practically given away. This condition is exceptional even in Illinois, and applies only to lands not now accessible to railroads. Mr. Rice says that lands in the Wilmington long-wall district sell for $50 an acre on an average, for a bed a little under 3 feet thick, or about 1 cent a ton; in other places in Illinois the land sells for as much as $100 an acre.

As a result of the keen competition in the East, Mr. Parker [b] reports that "there were few districts in which the margin between the cost of putting the coal onto the railroad cars and the price at which it was sold was as much as 10 cents a ton. In many States it is considerably less than 10 cents a ton. * * *"

"Competition" is often a relative term. A town may be near a small local coal field and a long distance from the nearest large competing field. Thus it may happen that although the town has good railroad connections with the distant coal fields and receives from them an abundance of coals, yet the freight rates may be so high that mines in the neighborhood may be able to pay seemingly exorbitant royalty as well as high rates for hauling, etc., and still be able to compete. Under such conditions, even though there is competition, it may not seriously affect mines that have the advantage of nearness, and the near-lying coal lands become valuable. For example, the value of coal lands near Colorado Springs, according to the county assessments, is more than three times the value that would be fixed by the Geological Survey under the regulations.

KNOWLEDGE OF COAL CONTENT.

A knowledge of the coal content of any land is obviously a large factor in determining the value of that land if the quantity and quality of the coal count at all. Land on which no coal is known to outcrop

[a] Bimonthly Bull. Am. Inst. Min. Eng., November. 1908, p. 1128.
[b] Idem, November, 1909, p. 1015.

or which is not even certainly known to be in a coal field will have a minimum value as coal land. The coal rights of certain large tracts have been purchased for 50 cents an acre on the possibility that they might contain coal, as, for example, in the Elkhorn field of Kentucky, now one of the most valuable fields in the United States. Some such purchases are in the nature of a speculation—"a gamble"—neither party to the transaction knowing whether there is coal under the land or not. In other purchases the buyer, from his knowledge of geology or by casually tracing exposed strata from some neighboring region where coal can be seen or is being worked, is able to assume with some confidence that coal is present in the land. In the heart of the Appalachian coal field there are thousands of acres that show hardly an outcrop of coal on account of the heavy growth of timber and vegetation. Mr. E. V. D'Invilliers describes[a] an area of nearly 200,000 acres in West Virginia as "a coal field without outcrop" prior to development. Some of the first purchases of this field were made for $5 an acre. Later purchases were for $12, and as prospecting developed the presence of rich beds of coal prices rose accordingly.

In another tract of 78,000 acres in the same State only one opening had been made on the coal. In the Block coal field of Indiana the important coal beds occur in small basins, separated by large areas bearing only thin coal beds. The coals are near the surface, but outcrop at few places because they are hidden by a mantle of glacial drift. This drift has also filled up and obscured the old preglacial valleys that may have cut out the coal. Here, evidently, no land is purchased as coal land before every 10 acres of it has been drilled, unless it be purchased as a pure speculation and at a price that will involve little loss if the land proves to be barren of coal.

On the other hand, many areas in the "bituminous" field of Indiana have been drilled so thoroughly and deeply and the coals run so regularly that it is possible to estimate the future recoverable tonnage within a few per cent. Such land should have a value equal to the royalty value less the cost of carrying the land to the time of mining and a slight margin for accidents and other contingencies. In Pennsylvania and other States, both East and West, many areas have been prospected so thoroughly that their coal content can be computed within 5 or 10 per cent. The value of such land may be estimated as closely as the price of a town lot. Evidently the owner of such a tract will not sell it for less than he thinks it worth, unless he is compelled to sell by financial or other stress.

It is under conditions of very thorough knowledge that the Pittsburg coal bed sells for $70 to $400 (as reported) per acre-foot, the price varying according to the accessibility of the coal to lines of transportation, etc. Mr. W. Weston, superintendent of the land and

[a] West Virginia Geol. Survey, vol. 2, p. 631.

industrial department of the Moffat road in Colorado, when asked what coal lands along his road were worth, replied that they were worth what they would bring in royalties.

Between the two extremes—one in which practically nothing is known of the coal content of the land and the other in which the coal content is known with great accuracy—lie the great bulk of the coal lands of the United States, though the areas about which nothing or little is known are now becoming very limited, for every year large districts are transferred from the unknown to the known side of the ledger. But considerable areas of partially known coal fields still remain—fields that have not been studied by a geologist, or that have been studied only in a reconnaissance way. In nearly all of these fields the area underlain by at least one workable bed is accurately known, but in some fields the work done has not yet given complete knowledge of all of the beds, and in these the price of land is much lower than it will be when the full coal content has been determined. In all of these fields, other things being equal and the buyer and seller having equal knowledge of the coal, the land will sell not for the value of the coal it does contain, but for the value of the coal it is known to contain. If it contains three beds and only one of them has been discovered, obviously the other two will not be included in computations of the value of the land. So, too, if there are only a few openings on the coal and, even though some of these show the coal to be of workable thickness, if it is not known whether they are on the same bed or whether the coal between the openings is likely to be workable, the buyer, in determining the maximum price he can pay, will figure on the smallest possible amount of coal the land may contain, as indicated by the facts known. In valuing lands whose coal content is only partly known, it is difficult to weigh justly the evidence available and to draw therefrom general conclusions that will be of undoubted value. If dependence be placed entirely upon available facts of local application only the most conservative estimate will be safe. Where, however, a broad knowledge of the same beds or of the same group of beds in other or adjacent areas is at hand, or where there is wide knowledge of the results of development under somewhat similar conditions elsewhere, it may be possible to draw general conclusions that warrant the assumption that the land contains much more coal than it would otherwise appear to contain.

Thus, on an undeveloped tract of land there may be only two openings on the coal, several miles apart, each showing workable coal. If this be the extent of the available knowledge, it may be thought safe to assume that only a few acres of workable coal exists around each of the two prospect openings. If, however, it may be inferred from the stratigraphy that the two openings are on the same bed, and if, by means of openings a few miles farther north, the coal can

be traced with great regularity for 50 miles northward, and the same way in other directions, the geologist may be justified in assuming that the bed maintains a workable thickness under the whole tract, and the land may be valued accordingly, some allowance being made for uncertainty. Again, if it is known that the bed just considered is usually underlain or overlain by other regular workable beds, even if these other beds have not yet been discovered on the land in question, such knowledge would justify the conclusion that these other beds are probably present, a conclusion that would increase the estimated value of the land, though with a great allowance for uncertainty.

If any or all of the beds are inclined to be pockety or irregular, the allowance for uncertainty must be correspondingly large. Where they are so irregular or pockety that a large percentage or most of the land in developed areas is barren, the unprospected areas must be rated as noncoal land until the presence and the thickness of the coal has been actually demonstrated.

Another condition that renders difficult the valuing of coal land is common in the West, where knowledge of the coal beds is derived entirely from exposures along an outcrop that extends in a more or less nearly straight line. How should the lands back from the outcrop be valued? In the East and parts of the West the mountains are thoroughly dissected and the crop line of a coal bed is of zigzag form—that is, it follows in and out of one ravine or valley after another, zigzagging back and forth in every direction. In such a region it is usually possible to get sections in different directions at right angles to each other and to observe any tendency toward thinning in any direction. But in parts of the West where the topography is young and simple and the country is little dissected it happens in many places that the outcrop extends, say, north and south, and there is little or nothing to show whether the coal holds its thickness back from the line of outcrop in an east or west direction. Under these circumstances experience has seemed to justify the assumption that the coal will run as far back from the crop at any one point as from that point to the nearest place along the crop where the coal becomes unworkable. Thus if a given coal has a continuously workable section for 10 miles along the face of an escarpment it is assumed that at the middle of such an outcrop the coal may extend back from the crop for 5 miles and for correspondingly less distances as the two ends of the workable outcrop are approached, so that the area assumed to be workable is roughly a semicircle with a radius of 5 miles. Reduction for uncertainty should increase in going back from the crop.

In general it may be stated that the valuing of coal lands ahead of actual mining must always be based on partial knowledge, but that

partial knowledge must be expanded or projected to cover the whole area to be valued. It is in this expansion that the personal judgment and experience of the valuer enters. First, the partial knowledge on hand must be so arranged as to show, if possible, how many beds of coal, or at least how many groups of coals there are, how regular each bed is, and how many beds underlie each acre, and at what depth. The number of beds is determined by comparing sections across all of the beds, taken at different places, and, wherever possible, tying individual beds together by actually tracing them or their horizon from point to point. Often these sections must be correlated by tracing from point to point some rock other than coal. In the West many coal horizons can be traced by a line or band of red clinker and reddened shale, caused by burning on the outcrop. The regularity of the individual beds is determined by comparing the sections on each bed over the whole field, also by comparing lines of sections in selected directions, in the hope that it may be possible to determine apparent thickening or thinning in some direction. By platting, both horizontally and vertically, all the dips noted in the field the structure of the field may be determined very accurately and the depth of each coal bed may be computed.

In areas where data are abundant and show that the coal beds are fairly regular it may be possible to assume the thickness, quality, and depth of coal with a large degree of probability, and to fix values accordingly. Where data are meager or where the coals appear to be thin and irregular the element of uncertainty becomes correspondingly large, and the appraised value of the land will be rapidly decreased away from the points of known workable coal unless additional data on the same coal-bearing rocks in other districts show that the few facts known in the district or tract under consideration fit in with the broad knowledge possessed. In a small detached field little or no coal may be exposed, but from knowledge gained in neighboring fields where the same rocks are known to carry several workable coals, it must be assumed that the same coals occur in the small field, unless direct evidence to the contrary exists, though because of lack of direct confirmatory evidence the price of the land in the small field must be reduced for uncertainty.

ACCESSIBILITY.

Accessibility is a most important controlling factor in the value of coal land. One of the largest single items in the cost of coal to the consumer is the expense of transportation from the mine to the point of consumption. This is seldom less than 50 cents a ton, and may be $6 or $8 or more a ton, as in many places in the West. Indeed, there are to-day large areas of coal, in both the East and the West, from which the present cost of transportation to the nearest commercial

market would be more than $8 a ton. Unless such a field can find or develop a local market it has only a prospective value until transportation facilities can be provided.

For a body of coal land that lies off the line of a railroad the prospective operator usually builds the necessary spur from the railroad to his own property. Ultimately the cost of building this spur does not impose a burden on the coal, as it is borne by the railroad company and paid from freight charges, but it may form an additional initial expense that may entirely prohibit mining unless the operator controls an extensive tract and has large capital to start with. For some such spurs the railroad companies supply the rails and the operators furnish the grade and ties.

Leaving out of account for the moment other elements that render coal inaccessible, the question arises—the cost of railroad spurs (except interest thereon) not ultimately standing against the coal—Should distance from the railroad lower the value of coal land?

In ordinary commercial practice every increase in the distance of coal land from a railroad or other line of transportation serves to decrease the value of the land, mainly because of interest charges to be carried through the uncertain time until the coal can be developed. Other things being equal, lands close to a railroad will be developed first, those farther back later—how much later is uncertain—those still farther back still later. Lands on a railroad may be opened up within ten years; lands farther from the road may have to wait another ten years, and so on. As a sum at 7 per cent interest, compounded annually, will double itself in ten years, every ten years that the land is likely to remain undeveloped cuts its value in two. Strictly speaking, lands back from a railroad are not "on the market" for development, although they may be the object of speculation.

As heretofore indicated, the law fixes the minimum selling price of coal lands which lie within 15 miles of a railroad at twice as much as lands lying beyond the 15-mile limit. Under the terms of the law the minimum price of lands that formerly lay more than 15 miles from a railroad is automatically doubled by the construction of a railroad that brings them within the 15-mile limit. If it be assumed that 15 miles is the limit to which a private operator can afford to build a switch, or over which he can afford to haul his coal by wagon for loading on a train, it is evident that, commercially considered, coal lands beyond the 15-mile limit are inaccessible and have no real present value as such, though they may have a prospective value.

Other factors also may render the coal more or less inaccessible, such as depth, high position in a hill, and intervening obstacles—rivers or mountains, say—between the land and the railroad. Where

an obstacle exists, it is practically necessary to consider the distance to the railroad as equivalent to the distance around the obstacle rather than over or through it in a straight line.

Depth is an element of inaccessibility that obviously works to the disadvantage of the coal, increasing the cost of mining, and, if beyond a certain level, decreasing the possible net recovery, and on both accounts decreasing the value of the land.

The limit of depth below which coal can not be mined is uncertain. Shafts practically 4,000 feet deep are operated in Belgium, and coal at about the same depth in England has been considered workable. This subject is more fully discussed by Mr. Fisher in his paper in this bulletin. Differences in the roofs and floors of coal beds and in the quality of the coal they contain make differences in the depth to which a bed can be profitably mined. In valuing the public coal lands the United States Geological Survey has conservatively taken 3,000 feet as the limit of workability. Further, the Geological Survey has taken the ground that if coal just beyond 3,000 feet in depth is non-workable, and therefore of no value, coal just within the 3,000-foot depth will be mined at the maximum expense and with the minimum recovery, and should therefore be priced at the minimum value, and that the value should increase from that minimum at 3,000 feet depth to a maximum at the outcrop.

In computing the depth of coal it has been the practice of the coal-land board to determine its depth below the level of a drainage way for all land within 2 miles of that drainage way, neglecting otherwise the intermediate topography. In broad plateaus underlain by coal at greater depths than 3,000 feet the coal has been considered workable for only a distance of 2 miles from its crop, it being considered accessible from the crop horizontally, though inaccessible vertically.

COST OF MINING AND MARKETING.

The cost of mining and marketing coal is determined by the sum of many expenses—initial expenses, or operating expenses, or both. Under ideal conditions the initial expense of opening and equipping the mine is the minimum, the thickness and quality of the coal allow the most favorable mining rate, the bed is without partings or other impurities requiring washing or hand picking, the roof is ideally strong or breaks down as desired for long-wall mining, the floor does not heave, water is at hand for the boilers outside but not in the mine, there is timber for the timbering, a town for the housing of the miners, the coal lies so as to facilitate hauling and draining, there is no gas at the face, and there is a steady market for mine-run coal on yearly contracts, with plenty of cars for its shipment.

These ideal conditions are not the normal conditions and seldom, if ever, exist together at one point. Competing fields may fall equally

below the ideal, so that only where some particular cost of mining becomes excessive does it enter into the value of the land. One mine may be favored in certain particulars, another in others, but in a large measure these advantages balance one another, especially among mines in any single district or field. The factor most easily allowed for is depth. The construction of a deep shaft not only costs money, the interest on which is a permanent charge against the coal, but increases the expense of mining by the cost of the power and of the care required for hoisting, and even more by the time required for hoisting; and the cost of operating such a shaft may ultimately increase the expense of the plant beyond the point of profit.

In the arid parts of the West lack of timber or of water may greatly increase the cost of mining. Partings or other forms of impurity may necessitate washing or hand picking. In mining thin beds it may be necessary to handle much roof or floor material. Even more serious may be the increased rate for mining thin beds demanded by the miners, and the rate increases rapidly with decrease in the thickness of a bed. For example, in the Indiana Block coal field the price for pick mining advances from $1 a ton for coal 3 feet 1 inch thick or more to $1.05 for coal between 3 feet 1 inch and 2 feet 10 inches, and to $1.10 for coal less than 2 feet 10 inches thick. Where coal is purchased in the ground at 1 cent to 2 cents a ton it is impossible to compensate the purchaser for the added cost of mining thin coal by reducing the purchase price; indeed, it may be that he would not be compensated even though no price were charged for such coal.

DEMAND.

Everything that increases the demand for coal at a given place enhances the value of the coal land from which that place is supplied. For example, the exhaustion of the natural gas in the Indiana gas field largely increased the demand for Indiana coal and to a perceptible degree affected the value of lands in those parts of the field that supplied the market relinquished by the natural gas. So, also, the opening of irrigation projects in the West, by enlarging the possible market, adds to the value of the adjacent coal fields.

On the other hand, by slightly manipulating freight rates or by building a new line of railroad, it is not infrequently possible to displace the coal from one field by the coal from some other field. This practice has virtually "killed" a formerly thriving field, and the price of coal lands there has dropped, just as the price of land in a small town drops when the principal manufactory moves to another town.

Again, a steady demand coupled with a limited supply forms the main cause of the higher prices of anthracite coal lands, of lands underlain by the Connellsville (Pittsburg) coking coal, and of cannel-coal lands. The supply of all of these coals is very moderate, and

the demand, except possibly that for the cannel coal, gives promise of holding good as long as the coal lasts, with no other coal in sight that supplies certain needs quite so well. As such coals become scarcer and scarcer the difference between their selling price and that of other coals becomes very great. Large steel companies have felt warranted in paying as high as $100 or more an acre-foot for coal of the Pittsburg bed to hold for future use.

ARTIFICIAL AND LEGAL RESTRICTIONS.

Artificial and legal restrictions seem destined to play a larger part in the value of coal lands in the future than in the past. It has already been noted that favorable or unfavorable freight rates can make or unmake a coal field. The passage and enforcement of a smoke law in a large city may seriously affect the coal field now supplying that city with smoky coal. In the same way the passage of mining laws for the protection of miners may increase the cost of mining the coal in some State and to that extent put the coal fields in that State at a disadvantage with other competing States and, by reducing the profits per ton, reduce the earning power of the coal and to that extent reduce the value of the coal in the ground. Uniform mining laws for all competing States would obviate the unfavorable effect of such laws on the value of the coal land.

On the other hand, trade agreements may act beneficially on the value of coal lands. It is generally true that good times and hard times balance each other. The mining companies may coin money during good years and carry on mining at a loss during hard times. If a company be well financed, it may for months actually sell coal at less than it cost to mine it, in pursuance of a policy adopted as cheaper in the long run than shutting the mine down. During hard times it has seemed wise to restrict production and maintain the price of the coal. A company that is not well financed may find it financially necessary to keep up its production by cutting the price, and as the lowest price will generally control the market the price drops all around, to the demoralization of the whole business. Prices once down are slow to recover. The result of a lowering of prices is clearly seen in the conditions existing in the coal trade in the East to-day, following the hard times in 1907. A corollary of these conditions is seen in the cheapening of the value of coal lands, and in the cheapening of methods of mining, with consequent smaller net recovery per acre, to say nothing of other undesirable results. The condition can be met in one of two ways, either by the absorption of the weaker companies by the stronger, with all of the attendant possibilities of monopolistic control, or, as suggested by Mr. Parker,[a] by govermental supervision and regulation, possibly by a system of licensing.

[a] Bimonthly Bull. Am. Inst. Min. Eng., November, 1909, p. 1016.

MARKET VALUE OF COAL LANDS.

BONDING VALUATION OF COAL LAND.

As has been stated, the market value of coal lands may be determined in three ways—by what coal companies estimate them to be worth when they wish to bond them, which may be taken as a liberal estimate; by the tax assessor's valuation, which may usually be considered a conservative estimate; and by the prices at which sales are actually made, which will usually lie between the liberal and conservative estimates.

The study of a single area of bonded coal land in one of the public-land States, the bonds for which are handled and guaranteed by one of the largest and most conservative brokerage houses after an examination and estimate by a widely and well known mining engineer and coal-mine manager, may serve to show the coal company's view of the matter when selling.

This land contains five beds of high-grade bituminous coal, ranging in thickness from 7 to 25 feet and having an aggregate average thickness of 60 feet. Each acre is computed to contain, "at the most conservative estimates," 100,000 tons of coal. This, it will be noted, is the gross, not the net tonnage, and on this gross tonnage the value is estimated on the "strictly conservative basis of 1 cent per ton of coal," the estimate giving as the value of each acre $1,000. For comparison it may be noted that the government price on some similar coal lands in Wyoming, where the land is estimated, on abundant data, to contain 75 feet of workable coal, ranges from $465 down, averaging probably less than $300. The basis of valuation here was 2 cents a ton for a net recovery of 1,000 tons per acre-foot, with a percentage reduction for all but the best bed, and with allowance for crop coal, depth, and uncertainty.

ASSESSMENT VALUATION OF COAL LANDS.

In comparison with such valuations as those just given it is of interest to note the valuations being placed on coal lands by county assessors. Figures have been obtained from several of the eastern coal fields, and also from Colorado, as typical of the West. The figures from Colorado were taken from the state auditor's report and supplemented by data supplied by the several county assessors. In Wyoming the coal in the ground is not taxed, but instead the coal is taxed on its cash value as mined, at the same rate as other property in that locality. In Colorado and in most other States developed coal lands are assessed at a much higher value than undeveloped coal lands. In the Pittsburg coal district of Pennsylvania, where the values are fixed entirely by that remarkably regular coal and where it is possible to assume knowledge of the coal content of any acre of land whether developed or not, the assessment is just the same for undeveloped as for developed lands. Undeveloped

lands elsewhere would be assessed the same as developed lands if we had the same knowledge of their coal content. In some places, as in part of Indiana, the coal is separated from the surface and is taxed at a uniform rate, the surface being taxed at rates depending on location or other features, in accordance with the general principles of land taxation.

County assessors commonly assess as coal lands only those being developed and treat undeveloped coal lands as grazing land or farm land, taxing them accordingly, as if they contained no coal. Developed coal lands are still more commonly assessed entirely on the value of the coals being worked, without regard to other coals that may underlie the land. In places the assessment varies with the average thickness of the coal. In other places, where the coal property is partly barren or worked out, the land is not assessed at two rates but an average assessment is computed, based on the amount of the coal that is being worked remaining in the ground.

In places where the coal land is most valuable the method of assessment has usually been worked out with much care and often with considerable geologic knowledge of actual conditions.

The following table gives data from selected points, including the range of assessment of coal in developed properties (exclusive of improvements) down to assessments on undeveloped lands off railroads and of small or unknown value, the ratio between the assessed and the assumed real value, and the assumed real value as estimated from the assessments.

Assessment value of coal lands per acre.

EASTERN COAL FIELDS.

Location.	Average assessments.	Range of assessments.	Ratio assessed to assumed value.	Assumed value.
Pennsylvania:				
Luzerne County		$8,000	8/10	$10,000
Clearfield County		2–50	1/4	8–200
Cambria County		10–50	1/3	30–150
Fayette County		400–600		
Westmoreland County		430–680		
Ohio:				
Belmont County		6–30		
West Virginia:				
Kanawha County		20–100	1/3	60–300
Raleigh County		200		
McDowell County		250		
Kentucky:				
Henderson County		10–12		
Tennessee:				
Claiborne County		25–40		65–100
Alabama:				
St. Clair County		1–6		
Indiana:				
Sullivan County		[a] 15		20–110
Greene County		[a] 15–35		
Warrick County		[a] 5–6		
Illinois:				
Grundy County		14–37	1/3	40–110
Bureau County		16		
St. Clair County		25–50		
Franklin County		15–35		25–50

[a] For coal only.

Assessment value of coal lands per acre—Continued.

WESTERN COAL FIELDS.

Location.	Average assessments.	Range of assessments.	Ratio assessed to assumed value.	Assumed value.
Colorado:				
Boulder County	$68.00		1/3	$204
Delta County	20.00	$20–50	1/3	60–150
El Paso County	51.66		1/3	155
Fremont County	29.46	10–40	1/3	30–120
Garfield County	37.40	10–50	1/3	30–150
Gunnison County	33.00	15–80	1/3	45–210
Huerfano County	28.00	2–70	1/3	6–210
Las Animas County	13.50	5–75	1/3	10–150
Mesa County	20.00		1/3	60
Pitkin County	16.34	4.50–30	1/3	13.50–90
Weld County	25.97			
Utah:				
Emery County		10		25

SALE PRICES OF COAL LANDS.

The market value of coal lands, as shown by actual sales, varies as it may be affected by the various factors previously described, ranging from almost nothing to the full royalty value, or even, as in lands carrying the Connellsville coking coal, to more than its apparent royalty value. Where, as they generally do, the lower prices represent not so much low value as incomplete knowledge or present inaccessibility, they do not show what the land would bring if its coal content were known or if it were accessible. The effect of lack of knowledge on the part of the sellers may be seen in the purchase by one of the large coal companies in the West of its present coal holdings at prices ranging from $80 down to $3 an acre, the price depending hardly, if at all, on the quantity and quality of the coal, but on the seller's knowledge not only of the amount of coal but of its value. The highest prices were paid for lands containing coal of which the seller had some knowledge. Many of the lower prices were the result of mere dickering. "They could get plenty of neighboring coal for so much, and if the seller did not accept their terms they would pass him by," an argument that usually got the land at the buyer's price, especially if the seller had little or no knowledge of the actual coal content of the land and its value.

Again, a large share of the sales recorded are on undeveloped property, much of it at some distance from railways, for in the reports of sales of developed property it is not usually stated how much of the price is paid for improvements and how much for the coal and coal land. Some of the data given in the following table were obtained by correspondence with the officers of large operating companies in the districts mentioned, some by personal interviews, and some from records of coal-land sales reported in the mining journals, from advertisements of coal lands for sale, or from other like sources.

Sale prices of coal land in the bituminous fields of the United States.

Locality.	Price per acre.	Price per acre-foot.
Pennsylvania:		
Pittsburg district	$800–$1,200	$110–$170
Connellsville district	1,200– 2,000	170– 300
Clearfield district	100– 250	.....
Cambria district	30– 150	.....
West Virginia:		
Fairmont district	35– 500	6– 60
Kanawha district	40– 300	6– 60
Pocahontas district	50– 350	10– 40
Virginia:		
Buchanan County district	50– 60	10
Kentucky:		
Southeastern Kentucky	10– 50	.....
Elkhorn district	200	.....
Western Kentucky	10– 40	.....
Tennessee:		
Jellico district	12.50– 125	4– 40
Claiborne County district	65– 100	.....
Alabama:		
Jefferson County district	20– 150	.....
Indiana:		
Terre Haute district	[a] 50	.....
Greene County district	100– 200	.....
Booneville district	60– 150	.....
Illinois	10– 150	.....
Grundy district	40– 110	14– 40
Rock Island district	50– 75	.....
Springfield district	10	13
Southern Illinois	25– 50	.....
Arkansas	15– 35	.....
Missouri	50– 75	.....
Kansas:		
Pittsburg district	100– 150	50
Colorado:		
Boulder district	50–187.30	.....
Carbon County district	20– 25	.....
Colorado City district	100–187.30– 500	22– 100
Elbert County district	30	.....
Johnson Mesa district	[a] 35	.....
Jefferson County district	7.50– 25	.....
Routt County district—		
Bituminous	50– 100	.....
Anthracite	150– 250	.....
Trinidad district	[a] 20– 60– 300?	15
Walsenburg district	100–187.30– 500?	23– 60
Wyoming:		
Sheridan district	30–106.50	.....
Rock Springs district	180– 430?	.....
Utah:		
Castle Valley district	30– 160	.....
New Mexico	10– 50	.....

[a] Mineral rights only.

Some additional facts may be given in extension and explanation of the table. The advance in the price of coal lands is well illustrated by examples from southwestern Pennsylvania. Many examples of this rise are cited in a book recently published, entitled "Coal fields of southwestern Pennsylvania."[a] To quote from that work (p. 49):

In 1885 large areas of Connellsville district coal lands were available for purchase at prices running up from $50 to $100 per acre. In 1890 to 1895 prices mounted up to $600 and $700 per acre. A belief was current that these prices were too high and would be lowered, but these coal lands at present command $2,000 to $2,500 per acre and will continue to advance beyond these figures, enormous though they appear.

In 1897 the average price of coal lands in southern Washington and eastern Greene counties, Pa., was less than $30 per acre—coal along the Monongahela River $100.

In the Fairmont, W. Va., mining district Pittsburg seam coal during the same period of time has advanced from $50 and $75 to $300 and $400 per acre.

[a] Boileau, John W., Coal fields of southwestern Pennsylvania, Pittsburg, 1907.

Hon. E. H. Gary, in an interview, stated:

Already we have 60,000 acres of coking-coal land in Pennsylvania, and are paying $2,000 an acre for all that is offered us.

In 1899 Mr. J. V. Thompson sold John W. Gates for his steel and wire interests 5,000 acres at $170 per acre. In 1907 Mr. Thompson paid $1,700 per acre for adjoining coal.

The Ellsworth Company purchased 7,000 acres of their coal for $37.50 per acre in 1899, and the Lackawanna steel interests paid at least $600 per acre for their proposition (adjoining) in 1907.

In 1898 the Illinois Steel Company * * * secured about 7,000 acres along the eastern outcrop of the new field (Klondike field). Some of the options were taken as low as $35 per acre—the latest purchases have been near $2,000.

In the Pleasant Unity district—that is, from Mount Pleasant to Latrobe—the coal was not considered good in early days. Near Hunkers Mr. Thaw purchased some at $180 per acre. To-day the price would not be under $3,000.

It is doubtless true that there have been special reasons for the very remarkable advances just described, yet advances appear to be taking place in nearly every coal field. Here and there are districts that, from lack of competition, have long enjoyed a prosperous trade, until the opening of a new railroad has brought new or cheaper coals into their market and has destroyed their trade. In such districts the price of coal lands has declined.

In Indiana excessive competition has forced prices down. In the early days of the Block coal field royalties of 20 to 25 cents a ton were often paid, and in Greene and Sullivan counties the royalties used to be about half that amount.

The action of other factors in depressing the prices of coal land is seen in the Trinidad field of Colorado, where the coal is mostly sold on large yearly contracts, at a relatively small margin, so that the profits on the coal obtained under any given acre are not so large as they would be in some other field, as in the Walsenburg and Canon City fields, which supply mostly the household trade at a greater profit per ton. A corollary of this small net profit per acre is seen in the lower prices per acre the land commands in that field, as compared with other fields of no more intrinsic value. In the Rocky Mountain fields, especially, dependence has been placed mainly on records of actual sales, which in some places are abundant, though in others only one or two have been obtained, and it is not known whether the figures cited are near the top or the bottom of the actual range. In general, the lower prices are for coals off the railroad. In some places the price is scaled down regularly as distance from the railroad increases.

BASIS OF THE GOVERNMENT VALUATION OF COAL LANDS.

WHAT IS COAL LAND?

The first step in any scheme of classification and valuation is to determine what is coal land. Any land underlain by coal that is of workable quality and quantity and exists under workable conditions is classed as coal land. In general, little or no question can arise. If the area is within the coal field as defined by the outcropping of workable beds, it may be presumed to be coal land, unless drilling or other exploration has demonstrated that there is no coal under it. There are large areas, however, where the presence of coal has been demonstrated, but the question arises, Is it workable? To some it may appear too poor, too thin, or too deep. How poor, how thin, and how deep coal can be successfully worked?

In general, it may be stated that anything that will pass as "coal" is workable so far as quality is concerned.

Successful attempts are now being made to utilize peat as fuel, and the Rhode Island "anthracite," which is almost graphite in character and is shot full of quartz stringers and veins, is being exploited with some hope of success. It remains to be seen what percentage of ash or other impurities a coal can contain and yet be successfully marketed. Coals containing 25 to 30 per cent of ash are marketed to-day under exceptionally favorable conditions, and in the laboratory, by the use of the producer-gas generator, coals with as much as 40 per cent of ash have satisfactorily yielded power. At the present time 30 per cent of ash appears to be a practical limit under the most favorable conditions, though in most markets 15 per cent is prohibitive. It may some day be possible to utilize bony coals containing as much as 50 per cent of ash.

The minimum thickness and the maximum depth of coal beds that can be profitably mined are discussed by Mr. Fisher in his paper in this bulletin. A somewhat careful study has been made of the conditions under which thin coals and deep coals are being mined in this country and in Europe. As a result of this study, all lands containing "coal" are classed as coal lands, except as defined in the "Regulations regarding the classification and valuation of coal lands" under the heading "Classification of coal lands," approved by the Secretary of the Interior April 10, 1909. The "Classification of coal lands," sections 1 to 5, inclusive, of the Regulations, is as follows:

(1) For the purposes of classification and valuation, coal deposits shall be divided into four classes:

(A) Anthracite, semianthracite, coking, and blacksmithing coals.

(B) High-grade bituminous noncoking coals having a fuel value of not less than 12,000 B. t. u. on an unweathered, air-dried sample.

(C) Bituminous coals having a fuel value of less than 12,000 B. t. u. on an unweathered, air-dried sample, and high-grade subbituminous coals having a fuel value of more than 9,500 B. t. u. on an unweathered, air-dried sample.

(D) Low-grade subbituminous coals having a fuel value below 9,500 B. t. u. on an unweathered, air-dried sample, and all lignite coals.

(2) Lands underlain by coal beds, none of which contain 14 inches or over of coal, exclusive of partings, of class A, B, or C, or over 36 inches of class D, shall be classified as noncoal land.

(3) Lands containing coals of classes A and B of any thickness at depths greater than 3,000 feet shall be classified as noncoal lands, except where the rocks are practically horizontal and the coal lies within 2 miles of the outcrop or point at which it can be reached by a 3,000-foot shaft.

(4) Lands containing coals of class C of any thickness at a depth greater than 2,000 feet shall be classed as noncoal land, except where the rocks are practically horizontal and the coal lies within 2 miles of the outcrop or point at which it can be reached by a 2,000-foot shaft.

(5) Lands containing coals of class D of any thickness at a depth greater than 500 feet shall be classed as noncoal, except where the rocks are practically horizontal and the coal lies within 1 mile of the outcrop or point at which it can be reached by a 500-foot shaft.

VALUES GRADED ACCORDING TO QUALITY AND USE.

Other things being equal, high-grade coals or coals that are especially suited to a particular use will command a higher price than coals of lower grade. In the public-land States of the West the abundance of coal increases as its grade decreases. Anthracite is limited to a few localities of a few square miles each; high-grade bituminous coals are much more extensive, but as compared with the lower-grade coals are confined to relatively small areas; low-grade bituminous and subbituminous coals cover or underlie thousands of square miles in the West; and lignites are found in even larger areas.

The higher-grade coals are therefore separated from those of lower grade by greater demand and smaller supply and, other things being equal, lands containing coal of the higher grade will command higher prices. The Government has therefore divided the coals found in the West into four classes, for the purpose of valuation, as expressed in the first section of the "Regulations regarding the classification and valuation of coal lands," given above.

Although the coals have been divided into four classes, these classes grade into one another; they are not separated by sharp lines; correspondingly the values placed on the coal of the different classes are graded from one class to another, and within each class values are graded by one-tenth of a cent a ton.

In determining the values to be given to each class of coal certain facts and factors were considered.

(1) It has been deemed necessary to place such a price on coal land as to make it unprofitable for private citizens to take up govern-

ment coal land simply to hold it for future mining, but at the same time the price should be so low for the man prepared to undertake immediate mining that it should not exceed the estimated royalty value of the coal, account being taken of the cost of carrying the investment at compound interest, with payment of taxes, etc.

(2) A royalty value of 10 cents a ton was taken as a fair average of the commercial royalties paid in the public-land States to-day for high-grade, noncoking bituminous coals at the time of mining.

(3) As under the present laws the maximum units of entry are 160, 320, and 640 acres, it was assumed that twenty years would be ample time to mine out all of one bed under that area if mining were undertaken within a short time after purchasing and continued with reasonable diligence. This gives ten years as the average time that each acre of land will be held from the time of the purchase to the time when the purchaser realizes on his investment.

(4) By taking 7 per cent compounded annually as a liberal interest charge, the purchase price should not be more than such sum as, when put at compound interest at 7 per cent for ten years, with ample allowance for taxes, would approximate the royalty price at the time of mining.

(5) To make ample allowance for all the contingencies of mining the purchase price should again be cut in half.

On this basis a purchase price of one-fifth the royalty value was fixed, the royalty value being assumed to be made up as follows:

Purchase price	$1.00
Interest on $1 at 7 per cent, for ten years, compounded annually	.97
Allowance for taxes and contingencies	.53
Cost at average time of mining	2.50
Allowance for contingencies of mining	2.50
Estimated royalty value	5.00

On the high-grade bituminous coals, therefore, a value of 2 cents a ton was placed, equal to one-fifth of a 10-cent royalty. This value became a base figure on which the other classes above and below high-grade bituminous were valued. Anthracite, semianthracite, and coking bituminous coals are by common consent placed above the high-grade noncoking bituminous coals. They sell for more on the market, and, as shown by conditions in the East, lands containing such coals sell well above other coal lands. Therefore lands containing such coals were valued at 2 to 3 cents a ton of their estimated coal content.

After a careful study of hundreds of analyses of well-known coals the line between high-grade and low-grade bituminous, noncoking coals was drawn at 12,000 British thermal units. Coals above that calorific value in an unweathered, air-dried sample are classed as

high-grade bituminous coal and valued at 1 cent to 2 cents a ton; those below that calorific value are classed as low-grade coal and valued at less than 1 cent and down to one-half cent a ton. Between one-half cent and 3 cents a ton, the minimum and maximum values, the valuations grade by one-tenth cent rises. A value of 1 cent given to a certain coal may indicate that it is considered either at the top of the low-class division (class C) or at the bottom of the high-class division (class B). Another coal of just a little poorer grade may be valued at nine-tenths of a cent a ton, and so on. Although the heat-giving value of a coal as expressed by British thermal units is taken as the most important factor in deciding on the value to be assigned to any coal, the physical properties and condition also receive due weight and consideration. All such factors as the shipping quality of the coal, its action on exposure to the atmosphere, the presence of partings or of sulphur or other impurities, the existence of any known conditions that will render mining easy or difficult or that will tend to add to or detract from its value on the market or to make its preparation for the market difficult are carefully considered.

With the low-grade bituminous coals are also placed the high-grade subbituminous coals or "black lignites" that show more than 9,500 British thermal units on an unweathered, air-dried sample. All coals whose heat value is below that limit, including also brown lignites, are grouped as class D, and are valued only at the legal minimum valuation, whatever their quality or thickness.

The grading of the value with the grade of the coal is theoretically in accord with modern practice, though actually and usually accessibility, nearness to market, and other local factors may so much outweigh differences in quality as to make it seem that quality has not been considered. Thus in Colorado the prices of land in the Boulder field, where the coal is subbituminous or "black lignite," appear to run as high as those for land in Routt County containing high-grade coals. If comparison is made between two fields equally accessible and equally near the same market and otherwise closely comparable, however, the difference is at once apparent. This may be seen by comparing the value of coal lands south of Pittsburg, where the Pittsburg coal is a low-sulphur coking coal, with the value of lands containing the same bed west of Pittsburg, where it is high in sulphur and a noncoking coal.

REDUCTION FOR NUMBER OF BEDS AND THICKNESS.

The value of 2 cents a ton for the highest grade of noncoking bituminous coal, it will be remembered, was based on the assumption that the coal purchased on the 40, 80, 160, 320, or 640 acres will all be mined out within twenty years. This makes no heavy burden on the purchaser if the land contains only 5 to 10 feet of coal. But

where purchasers take 320 or 640 acres of land that contains from 20 to 30 feet or more of coal, to mine out 1,000 tons per acre-foot within twenty years requires an average yearly output that rapidly becomes a great burden, or else the time of the recovery of the coal will be prolonged and the interest charges will make the last of the coal cost more than the royalty charge from which the price was computed.

These great thicknesses may result where there are a number of beds or where there is but a single bed, many of the beds in the West running from 30 feet up to 80 feet. Where there is more than one coal bed the regulations, therefore, provide that the normal value shall be fixed only for the bed most likely to be worked first, and that for a second bed only 60 per cent of the normal value is to be taken, for the third best bed only 40 per cent of the normal value, and for the rest of the beds 30 per cent of the normal value. Where the excessive thickness is found in a single bed, allowance is made for the longer time required for working it by treating it as a multiple bed—that is, as if it consisted of several beds that have locally come together. This is done only where the bed is over 15 feet thick. Where a bed is more than 15 feet thick the normal value is put only on 15 feet of it; the next 15 feet, or any part thereof, is valued at 60 per cent of the normal, the next 15 feet or part thereof at 40 per cent of the normal, and the rest of the bed, if it be so thick, at 30 per cent of the normal.

REDUCTION FOR DISTANCE FROM RAILROAD, DEPTH, ETC.

The value per ton above quoted is the normal or maximum value for any kind of coal. By the regulations the total price on any acre of land can not exceed $300, "except in districts which contain large coal mines where the character and extent of the coal are well known to the purchaser." Deduction is made from this normal for excessive distance from railroads and some other factors.

Prior to 1906, as before stated, it was the practice to charge the minimum prices of $20 and $10 for coal lands, according to their distance from a railroad. If a railroad was built within 15 miles of any of the lower-priced lands their minimum price was, by the law, automatically raised to the higher value. The same rule is applicable to the present system of valuation of coal lands according to their tonnage content, and lands more than 15 miles from a railroad are valued at one-half of the amount which would be fixed if they were within 15 miles of a completed railroad, the valuation price being automatically doubled when the lands are brought within the 15-mile limit.

In like manner, no allowance is made for existing or possible competition, distance from markets, or other factors that do not directly concern the coal itself. Those factors are variable and extraneous. The finding of a mineral lode may open up a new and

unforeseen market, and the exhaustion of the lode, possibly years afterward, may destroy that market. Or the carrying out of an irrigation project may give a neighboring coal field a small but permanent market. Competition, in like manner, is largely a matter of trade and commerce, subject to all the fluctuations of business and affected by factors with which the coal in the ground has nothing whatever to do. The price fixed is based on an average royalty under average conditions as they exist to-day, not on the 25-cent to 75-cent royalties paid at mines exceptionally well located—near towns or near large markets—nor yet on the exceptionally low royalties of 2 to 5 cents a ton paid under excessive competition, as in Indiana and Illinois.

Were the Government to vary the price of its coal lands with every variation in external conditions, as prices of town lots are raised or lowered, an excessive burden would be added to the cost of carrying the coal and endless dissatisfaction with the prices fixed would be created by the difficulty of giving proper weight and value to all the external factors.

On the other hand, it is possible to make allowance for factors that directly affect the coal bed and the ground under which it lies, such as depth, partings in the coal, poor roof, soft floor, topographic inaccessibility, burned outcrop, irregularity of bed, uncertainty of extent of bed, faulting, presence of eruptives, dikes, and sills—in short, any and all the factors that may affect the "fixed charge" representing the cost of mining and preparing the coal.

Thus allowance is made for depth, where the depth is more than a few hundred feet, grading down to a minimum price just within the limit of depth. In faulting, allowance is made not only for the zone of faulting, but for the fact that for practical purposes the throw may be so much that the coal on one side of the fault must be considered and treated as a second bed. In general, it has been the policy of the department to be conservative and to give the purchaser the benefit of the doubt, though, as previously observed, this statement must not be interpreted to mean that local lack of knowledge should outweigh good general knowledge.

The regulations for valuing public coal lands are as follows:[a]

(6) The price of coal lands of classes A, B, and C shall be determined on the basis of estimated tonnage at the rate of one-half to 1 cent per estimated ton for class C, 1 to 2 cents per estimated ton for class B, and 2 to 3 cents per estimated ton for class A, when the lands are within 15 miles of a completed railroad, and half that much when at a greater distance; but the price shall in no case exceed $300 per acre, except in districts which contain large coal mines where the character and extent of the coal are well known to the purchaser. When, however, topographic conditions affect the accessibility of the coal the land within the 15-mile limit may be given a lower valuation, but in no case shall it be placed at less than the minimum, and a graded allowance may be made for increasing depth, with the same restriction.

[a] See also sections 1 to 5 of these regulations, given on pages 37-38 of this bulletin.

(7) The rates per ton in the preceding paragraph are based on the assumption that only one bed of coal is present. If more than one bed occurs in any tract of land in such relationship that the mining of one will not necessarily disturb the other, then for the second bed there shall be added to the price of the first bed 60 per cent of the value of the second bed according to the schedule, 40 per cent of the value of the third, and 30 per cent of the value of each additional bed; but the estimated price for coal shall in no case exceed $300 per acre, except in districts which contain large coal mines where the character and extent of the coal deposits are well known to the purchaser. Where a bed is over 15 feet thick, the normal value shall be placed only on 15 feet; the next 15 feet or part thereof shall be valued at 60 per cent of the normal; the next 15 feet or part thereof at 40 per cent of the normal; and the rest of the bed at 30 per cent of the normal.

(8) The tonnage shall be estimated for the purpose of valuation on the basis of 1,000 tons recovery per acre-foot.

(9) The coal price of lands of class D shall be the minimum provided by law, $20 per acre when within 15 miles of a railroad and $10 per acre when at a greater distance.

(10) In all valuations of coal lands any special conditions enhancing the value of the land for coal-mining purposes shall be taken into consideration.

(11) When only a part of a smallest legal subdivision is underlain by coal the price per acre shall be fixed by dividing the total estimated coal values by the number of acres in the subdivision, but in no case shall this be less than the minimum provided by law.

(12) When lands which were at time of classification more than 15 miles from a railroad are brought within the 15-mile limit by the beginning of operation of a new road, all values given in the original classification shall be doubled by the register and receiver.

(13) Except in case of entries now pending or entries made prior to classification, review of classification or valuation may be had only upon application therefor to the Secretary, accompanied by a showing clearly and specifically setting forth conditions not existing or known at time of examination.

COMPARISON OF GOVERNMENT PRICES WITH COMMERCIAL PRICES.

The Geological Survey, working under the Secretary's rulings approved April 10, 1909, has not yet covered so large a territory as to afford numerous examples of valuations of coal for comparison. A large share of the sale values of which records were obtained in the public-land States are in areas mainly under private ownership, to which the Geological Survey has not yet given its attention. However, before the present regulations were approved large areas of coal land had already been valued by the Government's geologists, and while these values will generally be somewhat lower than the prices now being placed on corresponding coal land under the new regulations, comparisons may be instructive, especially comparisons with the minimum prices at which all government coal lands were sold a few years ago. Such a comparison is made in the following table, the valuations of coal land as made by the county assessors having been added, only values for developed property being given, according to the plan adopted in Pennsylvania, by which undeveloped lands are considered to be as valuable as developed lands if they are known to contain as much coal.

Comparison of sale prices of some coal lands and the prices of the same lands as fixed by the Government.

General location.	Sale price per acre.	Government price per acre.	Assessor's appraisal.
Northern Wyoming	[a] $105.50	[b] $40.00	.....
Do	[a] 35.00	[b] 40.00	.....
Do	[a] 29.50	[b] 30.00	.....
Do	[a] 50.00	[b] 40.00	.....
Do	[a] 30.00	[b] 30.00	.....
Southern Wyoming	[a] 62.50	[c] 170.00	.....
Central Colorado	[a] 187.30	[c] 176.00	$120.00
Do	[d] 500.00	100.00	120.00
Northern Colorado	[a] 187.30	[c] 103.00	200.00
Southern Colorado	[a] 187.30	[c] 135.00	200.00
Do	[a] 100.00	[c] 165.00	200.00
Do	[d] 60.00	[c] 80.00	150.00
Do	[d] 50.00	[c] 100.00	150.00
Do	[d e] 25.00	[c] 150.00	150.00
Do	125.00	[c] 120.00	150.00
Utah	[d] 156.00	[b] 50.00	.....
Do	[d] 150.00	[b] 50.00	.....
Do	[d] 160.00	[b] 75.00	.....

[a] Undeveloped property, usually back from railroad.
[b] Classified before April 10, 1909.
[c] Classification based on regulations approved April 10, 1909.
[d] Developed property.
[e] Coal rights only.

It will be noted that nearly all the sale prices quoted are those of undeveloped lands, most of which are not on a railroad. As before stated, the sale price of nearly all developed lands includes the cost of improvements, of which the value is not known to the writer, leaving an uncertainty as to the price of the land per acre, so that many data of that kind could not be used in this and in other tables.

The data at hand are too meager to serve as a source of general conclusions. On the whole, the government prices do not appear to run uniformly either above or below the purchase prices at which coal lands have changed hands between private parties.

The list does not include any of the higher-priced government land, but it may be of interest to note that the higher prices placed on government lands do not seem to have decreased their sale, but rather the contrary. Thus, to take as a concrete illustration the land office in Salt Lake City, it is stated that when the new government prices were first announced there was a general expression of doubt as to the sale of the lands, and the prediction was freely made that the new prices would absolutely tie up their sale. It was not long, however, before coal lands began to sell at the new prices, and the actual acreage sold in a short time far exceeded previous sales within a similar period. The sales have increased rather than decreased. The writer visited the office in Salt Lake City October 1, 1909, and found that in the preceding month, September, 27 sales had been made, ranging from 40 to 160 acres, at an average price of over $48 an acre, bringing into the office during the month a total of over $200,000, that 50 coal declaratory statements had been made, and 5 cash entries. A study of the sale of the highest-priced lands reveals

somewhat similar conditions. Thus in Wyoming coal declaratory statements have been made on four quarter sections in each of two townships, in one of which the prices range from $370 to $410 and in the other from $225 to $430 per acre. These facts in themselves would seem to be among the best arguments that the new valuations are not excessive or prohibitory. In fact, the statement was frequently heard in the field that in view of the way in which these values were determined persons contemplating buying placed a certain amount of reliance on them, regarding them as an index of the value and amount of coal the land contains.

LEASING OF PUBLIC COAL LANDS.

In his annual report for the year ended June 30, 1909, Mr. Ballinger, Secretary of the Interior, has recommended as follows:

> As regards new legislation, the present coal-land laws respecting the States and Territories, as well as Alaska, should be supplanted by an act fully meeting existing as well as future conditions. The inducements for much of the crime and fraud, both constructive and actual, committed under the present system can be prevented by *separating the right to mine from the title to the soil.* The surface would thereby be *open to entry under other laws* according to its character and subject to the right to extract the coal. The object to be attained in any such legislation is to conserve the coal deposits as a public utility and to prevent monopoly or extortion in their disposition. This may be accomplished either through a leasing system, by which the title would remain in the Government, under proper regulation and supervision by the Secretary of the Interior, or through the sale of the deposits, and in either case with restrictions on their mining and use which would control the minimum output and conserve the deposits as a public utility. I believe the most advantageous method will be found in a measure authorizing the lease or sale of the *coal deposits in the lands,* subject to forfeiture for failure to exercise the rights granted, under such reasonable regulations as may be imposed. An exploration period of at least one year upon a permit basis, at a nominal charge, would insure to the applicant the necessary preliminary knowledge upon which to make the lease or purchase of the coal deposits and venture the necessary investment for operation. The maximum unit authorized for this use could safely be made from three to five sections, provided no greater surface rights be granted than will give proper facilities to reach and extract the coal deposits.
>
> In case of the failure of the lessees or grantees to open and operate the coal deposits under reasonable limitations and to maintain an output reasonably suited to the deposits, and in case of combinations as to price and limitations of output, title should be forfeited by proceedings in court for that purpose. Government mine supervision would doubtless be necessary to enforce the conditions and limitations under the grant.

As two of the public-land States have now in operation a leasing system for the coal under their own public lands, it may be of value and interest to examine the system in use in those States. Wyoming has had a leasing law since 1907, and Colorado for a much longer period.

In Colorado, on November 30, 1908, there were 18,275 acres under lease, and these leaseholds yielded $104,456.42 in the biennial term

ending November 30, 1908. In the three biennial periods from 1902 to 1908 the income from royalties nearly doubled in each successive period, being $27,012.83 for 1902–1904, $49,077.05 for 1904–1906, and $104,456.42 for 1906–1908.

Some of the conditions of a lease in Colorado are as follows:

The lessee must begin to prospect within sixty days and to mine within six months if workable coal is found. He must open the coal and continuously and with reasonable energy develop it in a good and workmanlike manner, and after the first year he must pay a royalty on not less than a specified number of tons annually.

The lease gives him the right only to the coal and so much of the surface as is needed for the purpose of mining.

The lessee shall use good mining methods, timbering well, keeping the mine free from water and waste, protecting it against fire and flood, creeps and squeezes, and checking them if they occur, and shall extract the greatest amount of coal possible.

He is to allow the agents of the state board of land commissioners at any time to inspect any part of the mine or the mine's books.

The coal shall be weighed run-of-mine as it comes out of the mine and a record of it, as well as of all coal shipped by railroad or otherwise, shall be kept and preserved.

A report of the weight of all coal mined and shipped must be made on or before the 15th of each month.

On this basis payment must be made before the 15th of each month for all of the coal mined during the preceding month, at the rate of 10 cents a short ton, less one-twelfth of the minimum annual royalty, which shall have already been paid at the beginning of the year, whether any coal has been mined or not. This minimum royalty is a fixed yearly charge payable at the beginning of the year, but if the total royalty for the year shall exceed the amount of the minimum royalty the minimum royalty becomes a credit on the total royalty due.

All mining, timbering, and work done on the mine shall be subject to the supervision, approval, and order of the superintendent of the mineral department of the state board of land commissioners.

Failure on the part of the lessee to keep the terms of the lease will act to terminate the lease, and at the termination of the lease, either by forfeiture or expiration, the lessee shall return the property in good mining condition and without indemnification for improvements.

The lease may not be assigned or sublet without the consent and approval of the state board; it will not be construed as granting any other use than that of mining coal, nor for the mining, handling, or transportation of coal other than that mined on the land under the control of the state land board.

After testing several methods of measuring the coal for the purpose of computing the royalty, the state commission has adopted a method that is reported to be satisfactory both to the lessees and to the State. By this system the computation is made on the basis of the weight of the miners' cars. The monthly statements cover the gross weight mined by each miner, his check number, and the numbers of the entry and the room in which he mines. These statements are checked by the weights of lump and screenings and by railroad shipments. This makes an easy record to keep and to check. In case of dispute the coal in the mine is measured and the amount removed is computed. The cost of collection and inspection is stated to be about 5 per cent of the gross royalty income.

In Wyoming the lease grants the privilege of mining the coal for five years on the condition that the lessee shall pay to the State a fixed sum each year as "advance royalty," to apply on a royalty of 6 cents a ton on all coal mined and sold up to 25,000 tons, 5 cents if between 25,000 and 50,000 tons are mined and sold, 4 cents if between 50,000 and 100,000 tons, and 3 cents if more than 100,000 tons are mined each year; and that the lessee shall expend each year not less than $200 in development work.

If the lessee shall open and equip a working mine on the lease he shall have a preferred right to renew the lease for further periods of five years each on terms which may differ from those first agreed on, but in which the advance royalty shall not exceed $500 a year, to apply as before.

If coal is shipped from the leasehold by rail, a monthly statement and remittance must be made. For small mines a statement once a year only is required. No assignment of the lease shall be made without the consent of the State, and on the expiration or cancellation of the lease the property must be delivered in good condition.

The lease is subject to rights of way.

The lease may be canceled for failure to make payments or otherwise to keep its terms. A bond is required for the faithful performance of the terms of the lease.

DEPTH AND MINIMUM THICKNESS OF COAL BEDS AS LIMITING FACTORS IN VALUATION OF COAL LANDS.

By C. A. FISHER.

INTRODUCTION.

The subjects of maximum depth and minimum thickness of coal beds which can be worked at a profit have thus far received very little attention in this country, owing largely to the fact that only within the last few years has serious thought been given or organized effort made toward economy in the utilization of the country's coal resources. With the growth and development of the conservation policy two questions which are fundamental in an attempt to arrive at a reliable estimate of the coal supply naturally arise. (1) How far below the surface can coal be mined at a profit by the present methods or by the improved methods which may reasonably be expected in the future? (2) What is the minimum thickness at which a coal bed may be profitably worked, either as mined to-day or with the aid of mining machines especially devised to work in thin beds? The answers to these questions are quite as important as a knowledge of the areal extent of the coal fields in considering the total coal supply. The area of coal land is a fixed quantity which at present is fairly well known, but the maximum depth and minimum thickness of workable coal beds will be determined by the measure of success attained in overcoming the difficulties involved in mining deep beds and thin beds at a profit.

The mining of coal in this country, as elsewhere, has progressed along lines of least resistance. The thicker, more easily accessible, and more valuable beds have been worked first and the thinner, less easily accessible, and less valuable beds have been left. Unfortunately in some places this practice has rendered the thinner and less desirable beds worthless. Already in many places throughout the older mining districts of the Appalachian region, also in the Eastern region of the Interior province, the thicker and more valuable beds are being mined to their full extent, and attention is being turned toward the development of thinner and less valuable beds. In the Western region of the Interior province, where coal is generally less abundant, the mining of thin beds has been carried

on rather extensively for some time and apparently at a profit. In the Rocky Mountain province, where coal mining is a comparatively new industry, a number of thin coals have been worked independently for one reason or another in the presence of thicker beds, and here and there mining has been extended to considerable depth.

It is proposed to discuss in this paper some special features of the coal-mining industry in this country and elsewhere. Coal mining in the United States has not reached so advanced a stage as it has in Europe and especially in England, and a comparison of methods will, it is believed, be instructive and helpful in the endeavor to make a wise disposition of the coal resources of this country.

MAXIMUM DEPTH OF COAL MINING.

FOREIGN COUNTRIES.

General conditions.—Coal mining at considerable depths has been carried on successfully abroad, especially on the European Continent, throughout the British Isles, and in Australia. Such mining is probably due to a number of conditions which vary with the locality where the deep workings occur; the most common, however, is the exhaustion of coals nearer the surface by long-continued working. In some places deep mining is done because the operators are more willing to lift coal from a deep shaft at the place where it is to be used, or from which it can be most economically shipped, than to bring coal mined at less depths elsewhere to this point by surface haulage. Still another cause may be the presence of steep dips in the rocks around the rim of a deep structural coal basin, so that a relatively small proportion of the coal of the basin lies near the surface and exploitation, even though followed but a short time, has reached considerable depth. Other factors, such as high surface relief in a coal field, may necessitate mining under great cover, which is generally the equivalent of great depth.

Belgium.—The deepest coal mining of which the writer has been able to obtain any record is in Belgium, where moderately thin coal beds are being successfully worked at a maximum depth of 3,937 feet. Several coal shafts in Belgium exceed 2,400 feet in depth, and mining levels ranging from 2,700+ to 3,000+ feet are not uncommon. The Produits collieries, in the vicinity of Mons, have reached the greatest depth given above, with results that are satisfactory so far as difficulties arising from excessive temperature, squeeze, and crushing strain due to the pressure of superincumbent strata are concerned. Under the commercial conditions existing in that country the cost of such mining is apparently not prohibitive. Definite figures are not at hand for comparison, but in general the cost of labor is less and the selling price of coal higher in Belgium than in this

country. Some facts concerning a number of the deepest workings in Belgium are given in the table on page 65.

England and Wales.—In England and Wales, where coal mining has probably been carried on longer than in any other part of the world, the deepest coal workings about which it has been possible to obtain information are those of the Rams mine of the Pendleton colliery at Manchester, which attain a depth of 3,483 feet. The thickness of the coal bed varies from 2 to 6 feet. At the Ashton Moss and the New Moss collieries, both located in this district, workings have been carried to depths of 3,360 and 3,300 feet, respectively, and at other places in Lancashire, also in Yorkshire, Staffordshire, Somerset, and Glamorgan counties, coals are being mined at depths ranging from 2,130 to 3,150 feet. In these deep workings no insuperable engineering difficulties have been encountered; nor has the cost of mining at these great depths proved prohibitive. It is the consensus of opinion among men of wide experience in deep coal mining throughout the United Kingdom that nothing less than 4,000 feet should be regarded as the limit of practical coal mining.[a]

Scotland.—The greatest depth of coal mining reported in Scotland is 2,700 feet, in a mine at the Niddrie collieries, Portobello, near Edinburgh. The coals there are in a structural basin, the lowest point of which, under the town of Musselburgh, lies at a depth of more than 4,000 feet.

France.—In France deep coal mining is not uncommon. E. Lozé, in correspondence concerning the depth of collieries in France, makes the statement that coal-mine shafts extending to a depth of 1,200 to 1,500 feet were formerly considered deep, but that at present several exceed that depth and some reach 3,000 feet.

Germany.—According to information obtained by correspondence with the late Dr. H. Wedding, coal mining in Germany reaches a depth of 3,117 feet near Chemnitz. In the Rhenish-Westphalian mining board district of Dortmund coal beds are being exploited at a maximum depth of 2,625 feet. The depths in this district range from about 1,000 to 2,600 feet, the average being 1,700 feet. It is predicted by Schultz-Briesen,[b] one of the foremost German authorities on the subject, that the average depth of coal mining in this particular field will exceed 2,000 feet in the next decade. In the northern part of the district along Lippe River the coal measures have been reached by drilling and found to contain good beds at depths ranging from 2,300 to 3,281 feet. It is believed by Schultz-Briesen that these coals will be exploited within the next few years. In regard to deep coal mining in Westphalia, the same author makes the following statement in a communication to the Royal Commission on Coal Supplies:

[a] Final Rept. Royal Comm. on Coal Supplies, pt. 1, p. 4.
[b] First Rept. Royal Comm. on Coal Supplies, 1903, App. II, p. 335.

The technical progress made in the last twenty-five years in the machinery applied, and the improvements in the underground system of mining operations, go to prove that we have not by any means arrived at a fixed standpoint with regard to such progress, and thus the German miner has no doubt that not only is there a possibility but the greatest likelihood of pushing down to a depth of 1,500 meters (4,921 feet) or more, and of mining coal there at a commercially profitable cost.

It is noteworthy that this opinion is shared by Stassert and other coal experts on the Continent.

Australia.—A shaft known as the Birthday has been sunk to a depth approximating 3,000 feet by the Sydney Harbor colliery in New South Wales for the purpose of reaching a coal bed not exceeding 3 feet thick. This coal bed outcrops 75 miles away, at Newcastle, also on the coast, where shipping facilities are equally good. It is significant that another shaft was sunk to the same bed after the Birthday shaft had proved the thickness of the coal.

Experience gained by deep mining abroad.—Deep coal mining has advanced to such an extent in Belgium, England, France, and Germany that many of the obstacles which arise in working coal at depths of 2,000 to 4,000 feet have been actually experienced and therefore have ceased to be matters of conjecture. From the knowledge gained by these deep workings there appear to be no engineering or mechanical difficulties which can not be successfully overcome within the limit of 4,000 feet. Certain advantages accompany the disadvantages in deep coal mining. The increase of pressure due to depth has been found in some mines to assist in working the coal. The greater the depth the less is the danger of disturbing valuable buildings, railroads, and canals on the surface as a direct result of taking out the coal. This item is an important one in a thickly populated reigon. The almost total absence of water at the lower levels often eliminates the item of drainage.

Some of the disadvantages in deep coal working are the difficulty of maintaining roadways and timbering and the increased percentage of small coal obtained. The chief difficulties which practical experience has brought out, however, are high temperature and cost. The former can be overcome to a certain degree by mechanical means, but such means involve an additional cost which in continuing deeper eventually reaches a figure that exceeds the selling price of the coal. Experience in these regions of deep mining has shown that the rate of increase of temperature with depth is by no means uniform but varies in different localities and under different geologic and structural conditions, so that it is impossible to predict what temperature may be encountered at any given depth. The reduction of temperature by strong currents of dry air has proved in a measure successful, but the amount of such reduction is not great. It has been found that the maximum temperature consistent with human labor is greater than 93° F., provided the air is dry.

The amount of lump coal which can be taken from a coal bed at great depths depends not only on the character of the coal but also on the nature of the bed. If partings of dirt which take up the crush occur in the bed, the coal can often be taken out in moderate-sized blocks. The character of the strata inclosing the coal is also an extremely important factor in determining the effect of crushing stress at great depth. Of course, a poor roof or floor causes trouble in mining coal at any depth, but with increased depth the difficulty is greatly augmented. In fact, this point is emphasized by one English authority of wide experience in deep coal working, who states that the ability to reach great depths in mining depends very largely on the natural hardness and strength of the strata. Room-and-pillar methods of mining are universally abandoned in deep mining, and long-wall working or some modification of that system is employed. Mining machines are also strongly recommended for great depths.

UNITED STATES.

General conditions.—For the sake of convenience the coal fields of the United States have been classified by M. R. Campbell into six provinces—the Eastern, Interior, Gulf, Northern Great Plains, Rocky Mountain, and Pacific Coast provinces. These in turn have been subdivided into regions, fields, and districts. The Eastern province includes the Appalachian Mountain region, the Anthracite region of eastern Pennsylvania, and the Atlantic Coast region, comprising a number of small scattered fields in Virginia and North Carolina. The Gulf province comprises the coal and lignite bearing rocks of the Gulf States. It is subdivided into the Mississippi and Texas regions. The Interior province comprises the large coal areas of the Mississippi drainage basin. Its subdivisions are the Northern region, including the coal field of Michigan; the Eastern region, including the Illinois, Indiana, and Kentucky fields; the Western region, including the Iowa, Missouri, Kansas, and Oklahoma fields; and the Southwestern, or central Texas coal field. The Northern Great Plains province includes the lignite and subbituminous coal fields of North and South Dakota, Wyoming, and Montana, and is subdivided into the Fort Union, Black Hills, Judith Basin, and Assinniboine regions. The Rocky Mountain province includes the coal regions of the Rocky Mountains, nine in all, besides a number of scattered areas. The Pacific Coast province consists of a number of small isolated coal fields lying along the coast.

In the United States coal is now mined at relatively shallow depths; the deepest mining, which occurs in the Anthracite region, reaches about 2,200 feet. The absence of deep mining in this country is due to the fact that in the Appalachian region, where coal mining began and the greatest development has taken place, the

coal beds with few exceptions are near the surface, and the structure of the rocks is such that the coal beds do not extend to great depth. Likewise in the Northern and Eastern regions of the Interior province, where mining has gone on for a long time, the structural basins are relatively shallow and the coal beds are near the surface. In the Rocky Mountain province, where the coal generally lies in deep structural basins, mining is not far advanced and for the most part is confined to the margins of the basins.

Eastern province.—The deepest coal mining in the Eastern province—also the deepest in the United States, so far as the writer has been able to learn—is in the Anthracite region, where, as previously stated, a maximum depth of about 2,200 feet has been reached. The coal beds of this region probably extend to greater depths, and as they furnish the best fuel in this country they will doubtless be worked at greater depths in the future. The deepest workings in the bituminous fields of western Pennsylvania probably do not exceed 1,000 feet; in Ohio and in West Virginia, which includes the New River and Pocahontas fields, the present depth or cover of coal mining is still less. The same maximum is found in eastern Kentucky, Tennessee, and Alabama, except possibly at a few places. In fact, throughout the Appalachian region, with the exception of the south end, or that part in northeastern Alabama, where there are some deep basins, the maximum cover of the unworked coal beds probably does not exceed 2,000 feet. It is worthy of note that in the Appalachian region, where the physical conditions, such as hardness of rock and ability to withstand crushing, are favorable for deep mining, the coal beds do not occur at great depths.

Interior province.—Throughout the Interior province the workable coals, with the exception of the beds in the southern part of the Western region, do not extend to great depth but generally lie in shallow basins.

In the Michigan coal field the beds are nearly flat and the cover does not exceed 200 feet in thickness. The coal beds of the Eastern region occur in a wide, shallow basin covering the greater part of Illinois and small portions of Indiana and Kentucky. The greatest depth of coal mining reported in this basin is 1,003 feet, near Assumption, Ill. Throughout Iowa, Missouri, and Kansas moderately shallow coal mining prevails, the range being from beds that outcrop to those about 300 feet deep; but farther west and south in this region, in eastern Kansas, Oklahoma, and western Arkansas, greater depths have been attained, the maximum reported being about 800 feet in the McAlester district of Oklahoma. It should be mentioned in this connection that a 1,170-foot shaft was sunk in the vicinity of Atchison, Kans., but no extensive operations were ever carried on from this level. The deepest coal-mining shaft reported in Arkansas is one of 480 feet.

Very little information has been obtained concerning mining conditions in the Southwestern region of Texas, but such as is at hand indicates that the workings are not deep.

Northern Great Plains province.—The deepest coal mining in the Northern Great Plains province is in the Great Falls field of the Judith Basin region, where a shaft has been sunk to a depth of 480 feet for coal in the lower part of the Kootenai formation. In the Fort Union region, which is by far the largest subdivision of this province, the deepest mines, located near Sheridan, do not exceed 300 to 400 feet in depth, and in the lignite areas to the northeast the average depth is considerably less. In the Black Hills region, where mining has been going on for many years, the maximum depth is about 350 to 400 feet. The Assinniboine region of northern Montana has very shallow mining, the greatest depth reported being 250 feet.

Rocky Mountain province.—In the Rocky Mountain province the deepest mine about which information has been procured is mine No. 1 of the Union Pacific Coal Company, at Rock Springs, Wyo., where a depth of 2,000 feet has been reached. At Cumberland, in the southwestern part of the State of Wyoming, in the Hams Fork region, a depth of 1,600 feet was reported about two years ago. This depth is probably exceeded at present. The next mine in point of depth is the Spring Gulch mine, near Carbondale, Colo., in the southeastern part of the Uinta region, where coals lying under the Grand Hogback and having a covering of approximately 1,500 feet are worked. At Cokedale, Mont., a bed of coal was formerly worked to a depth of 1,300 feet. The coal was a coking variety and was badly crushed.

In the Raton Mountain region of southern Colorado and northern New Mexico the Starkville mine, in the vicinity of Fishers Peak, is at present working under about 1,100 feet of cover, and this depth will rapidly increase as the coal directly under the summit of the peak is approached. A depth of about 1,000 feet has been attained in the South Canyon mine, south of Glenwood Springs, Colo., and in the Central mine at Canon City, Colo. The depth of coal mining in other parts of the Rocky Mountain province, except possibly at a few places, ranges from 50 to 600 feet.

Of the eight regions included within the Rocky Mountain province five are large structural basins in which the coal beds outcrop more or less persistently around the margins, and if these beds are continuous underground they must reach great depths in the centers of the basins. The coals are late Cretaceous to Tertiary in age, and are contained for the most part in rocks which are prevailingly soft, consisting of slightly consolidated sandstone and sandy shale. It is generally recognized that soft rocks are more susceptible to crushing and squeezing, due to the pressure of superincumbent strata, than hard

metamorphosed sediments, and that, other things being equal, in mining under deep cover more difficulty will be encountered in maintaining roadways, etc., in soft rocks than in harder rocks, providing the latter are not faulted or too much jointed. It is obvious that as mining is extended to greater depths in the soft coal-bearing rocks of the West more or less difficulty may be expected from the above-mentioned sources. The long-wall method of mining, which is better suited to great depth than the room-and-pillar method, will probably have to be employed at depths of 2,000 feet and possibly less in some localities. When the room-and-pillar method is used in deep workings, in addition to the general difficulties resulting from crushing and squeezing, there sometimes occurs an explosion or blowing to pieces of the pillars over a considerable area in the mine. This phenomenon, known to the English miners as "outburst," is believed by some of them to be due to the presence in the coal of gas, which, being under great pressure in the pillar, explodes. Some observers believe that these outbursts are most prevalent in coals subject to spontaneous combustion, and that usually they may not be expected at depths less than 1,500 feet. Boring holes in the coal, also in the roof and floor, for the purpose of allowing the gas to escape, has been suggested as one remedy, and changing from the room-and-pillar method of mining to the long-wall method as another. Outbursts of this nature have been reported from mines in Utah; also from mines in Canada, where they are locally known as "bumps."

As previously stated, the long-wall method or some modification of it is recommended by English miners for deep coal workings, and this method will doubtless be adopted in recovering the coals of the deep basins of the West. With the advantages gained by the experience in deep coal mining abroad there should be no insuperable difficulties, either physical or commercial, in mining the coal from the bottoms of these basins to a depth of at least 4,000 feet.

Pacific Coast province.—The greatest depths reported to which coal workings have been carried on the Pacific coast are found in Washington, where, at the Roslyn mine, a depth of 700 feet has been reached. In the Coos Bay field of Oregon and in central California the maximum cover of coal workings is about 500 and 300 feet, respectively.

CONCLUSION.

In the United States to-day coal lying more than 3,000 feet below the surface is being disregarded in connection with the disposition of coal lands on the public domain, whereas coals below 3,000 feet are being successfully and profitably mined in Belgium, England, Wales, France, and Australia, a group of countries which supply about half of the world's production. Furthermore, all coal

beds down to a depth of 4,000 feet were included by the Royal Commission on Coal Supplies of England in their estimate of the total coal resources of that country as early as 1871, nearly forty years ago. This position is significant as representing the best thought of a country in which coal mining originated and which at the present time ranks second only to the United States in the production of coal.

Of course it should be recognized that as coal mining in different parts of the United States is extended to great depths there may be localities in which the difficulties arising from deep mining may combine in such a way as to make further operation impracticable; it is believed, however, that such localities will be highly exceptional and that in general the obstacles encountered in this country will be no greater than those which have been successfully overcome in other countries.

WORKING OF THIN COAL BEDS.

FOREIGN COUNTRIES.

General statements.—The mining of thin coal beds, either in conjunction with other beds or independently, has for a long time been carried on with profit abroad, especially in England and Belgium. Special methods have been devised for recovering these thin deposits, and men have been trained from boyhood to work beds of ordinary bituminous coal 12 inches thick, either independently or in conjunction with thicker and more valuable beds. Cannel coal has been mined in beds as thin as 8 inches. It has also been found profitable to work these thin beds not only in conjunction with thicker beds but in groups of eight or ten beds.

The conditions which make it possible to mine coals in thin beds profitably are (1) exceptionally good quality, (2) exhaustion of more valuable beds, (3) intimate association with thicker and more valuable beds of coal, fire clay, etc., (4) low labor cost and high selling price of coal, (5) geographic isolation of thin coals, which prevents them from coming into competition with more valuable beds, (6) especially favorable conditions of accessibility, such as will permit mining by stripping the surface, etc. One or more of these conditions has probably been the controlling factor in each locality in bringing about the mining of thin beds abroad.

England and Wales.—The thinnest bed of coal concerning which record has been obtained that is mined in England at the present time has a thickness of 8 inches. It is cannel coal and is mined in conjunction with other beds. At three different localities in East Lancashire beds of coal 10 inches thick are worked independently, and at several places in this county, as well as in Yorkshire, Shropshire, Gloucester, Somerset, and Monmouthshire, beds 12, 16, and 18 inches

thick have been and are being mined at a profit, either independently or with thicker beds. The Lower Foot bed, which has a thickness of 11 inches, is worked in conjunction with thicker beds. At the Braysdown colliery at Bath, in Somerset, a bed 12 inches thick is being mined in connection with six other beds having an average thickness of 17½ inches, and at Dowlais, in the South Wales coal field, 27 men employed on a 21-inch bed produce 12,690 tons annually, or 470 tons to the man.

Belgium.—In Belgium the Little French, Deux Haies, and Harlem beds, each of which has a thickness of less than 12 inches, are mined. The Grand Gaillet and Grand Cornaillette beds, which are each less than 14 inches thick, are worked on account of their excellent quality as gas coal; also the St. Amand bed, which yields a domestic and coking coal and has a thickness of only 13 inches. In view of the fact that all the coal beds in Belgium lie at considerable depths below the surface, the mining of these thin beds at a profit is even more remarkable.

Scotland.—The mining of thin coal beds in Scotland is also more or less common. In Lanark and Sterling counties beds ranging from 12 to 15 inches are worked to some extent. In East Scotland, however, at the Westrigg, Avonhead, and Brownyside collieries, beds 15, 13, and 14 inches thick, respectively, are mined, and many beds less than 2 feet thick are worked on a comparatively extensive scale. The thin beds thus worked rarely exceed 600 feet in depth and are not highly inclined.

Other foreign countries.—Thin coal beds are mined also to a greater or less extent in Germany, France, and other foreign countries.

UNITED STATES.

General conditions.—The mining of thin coal beds in the United States is not so generally practiced as in foreign countries, nor is the mimimum thickness worked as small as that abroad, yet many thin coals are worked in this country. In general, the factors that bring about the mining of thin coal abroad apply also to this country, but here not all of these factors dominate, owing to the fact that the mining of our coals has not reached so mature a stage. Here the exhaustion of the thicker and more valuable beds has only recently begun to be felt, even in the oldest mining district. Specialization in utilizing the coals of this country has not been sufficiently developed to afford in many localities such a market for particular coals that they can be mined at a profit no matter how thin.

Eastern province.—In the Eastern province perhaps the thinnest beds worked are to be found in the area of most valuable coal, the Anthracite region. Here, according to information obtained

orally, coals as thin as 18 inches are mined in conjunction with other beds. In the bituminous region of western Pennsylvania the thinnest beds worked are in the western part of the Clearfield district, where the Gassam mine works a bed ranging from 48 down to 17 inches. In West Virginia the thinnest coal bed worked commercially is the Sewell. At Sewell the Longdale Coal and Iron Company formerly worked this bed down to a thickness ranging from 20 to 24 inches. It is not uncommon in the New River field, where the Sewell coal has been extensively mined, to find the bed worked with a thickness varying from 24 to 30 inches. The coal is of high grade, clean, usually without parting, and generally inclosed by an excellent roof and floor. In the Georges Creek field of Maryland, with the approaching exhaustion of the "big vein," development work has begun on the Lower Kittanning coal, which in places is about 2 feet thick. Throughout eastern Kentucky and Tennessee the Blue Gem bed is the thinnest worked, varying from 22 to 24 inches. This bed furnishes a domestic coal of exceptional quality. It has been reported from a reliable source that a large area which prospect holes have shown to be underlain by the Blue Gem bed with a thickness of only 22 inches has recently been leased. In other parts of the Eastern province, so far as the writer has been able to ascertain, there is nothing exceptional about the thickness of the coal beds mined, but personal observation in all the larger northern Appalachian fields indicates that there is a marked tendency toward the mining of thinner beds along with the thicker as the latter become more and more nearly worked out.

Gulf province.—The coals of the Gulf province are mainly lignite, and their development up to the present time has not been extensive except in the Southwestern or Texas region. The thinnest bituminous coal reported as worked in this region is 19 inches thick.

Interior province.—In the Interior province, especially throughout the Northern and Eastern regions, only moderately thin coal beds are mined, but in the Western region some of the thinnest coal beds mined in the United States are to be found. The minimum thickness of coal mined in Michigan, or the Northern region of this province, is 24 to 26 inches, which can not be regarded in any way exceptional. Throughout the Eastern region, in Illinois, Indiana, and Kentucky, 2 feet is about the minimum worked. In both of these regions this large minimum is probably due to the prevailing presence of thick coal beds which up to the present time have not been regarded as even approaching exhaustion. As previously mentioned, a very different condition prevails in the Western region, which includes Iowa, Missouri, Kansas, Oklahoma, and Arkansas. In all these States except the last two coal is not abundant nor does it occur in especially thick beds. The thin beds are as a rule easily accessible,

occurring at moderate depths, and are located at some distance from thicker and better beds.

According to the Iowa state mine inspector's report for 1908, there were 20 mines in Taylor, Page, and Adams counties, in the southwestern part of the State, located on a coal bed 14 to 18 inches thick, with an average of about 16 inches.[a] Of these 3 were shipping and 17 local mines. Their combined annual output amounted to 45,666 tons. Of course, the mines described above are not large and many might properly be regarded merely as country banks. Nevertheless, they are supplying at present at least a portion of the coal consumed in that part of the State and competing successfully with larger mines on thicker and better beds. These coals do not have the advantage of being high grade; they are, in fact, low-grade bituminous coals.

According to the Missouri state mine inspector's report for 1902 and the nineteenth and twenty-first annual reports of the Missouri bureau of mines for 1905 and 1907, respectively, 32 mines were operated on coal beds having a thickness ranging from 12 to 20 inches. Among these the largest output was from the Diamond Coal Company's mines in Lafayette County, which in 1907 yielded 49,786 tons. Records of three other mines are given in the annual report of the bureau of mines for 1907—one in Clay County, where the Missouri City Coal Company works a 20-inch bed, with an annual production of 40,590 tons; another in Lafayette County, where the Farmers Coal Company works a 19-inch bed, with an annual production of 37,600 tons; and another in Lafayette County, where the Laning-Harris Coal and Gas Company works an 18-inch bed, with an annual production of 27,534 tons. According to the nineteenth annual report of the bureau of mines, for 1905, page 249, a mine on an 80-acre lease, with $2,500 invested in equipment, was operated by Joe Bradley on a 12-inch bed. In Grundy County in 1907 the Trenton Mining Company worked a 19-inch bed by a shaft 240 feet deep and produced 11,040 tons. According to R. S. Thomas, inspector of mines, a 16-inch bed in the same county was worked by a shaft 225 feet deep. The production of the mine is not given. In 1907 the Kierstead Coal Company of Lafayette County mined an 18-inch bed by a shaft 90 feet deep, the production being 18,176 tons. In addition to the mines mentioned above, there are a number of small mines or country banks working beds 12 to 18 inches thick, that range in annual output from 100 to 1,000 tons. Though none of the mines described above can be regarded as large, the Diamond Coal Company's mine, with an annual production of nearly 50,000 tons, can not be considered a country bank.

[a] The most recent publication on the coals of Iowa (Hinds, Henry, Coal deposits of Iowa: Ann. Rept. Iowa Geol. Survey, 1908, pp. 381, 385) gives the average thickness of the Nodaway bed in these counties as varying from 16 to 20 inches, with an average of about 17 inches.

In the Osage City region of Kansas coal beds as thin as 15 to 18 inches are worked by small mines. In the Weir-Pittsburg region, the largest coal-mining field in the State, the minimum thickness of coal worked ranges from 18 to 24 inches. At Arcadia coal 20 inches thick is mined by stripping, also by drifts and shafts; this coal, owing to its excellent quality, competes successfully with the Weir-Pittsburg coal.

In Oklahoma the mining of relatively thin coal beds in a small way for local use is reported from a number of localities. In the northeastern part of the State (the Muskogee region) the McAlester coal, which in its northern extension from the McAlester district becomes thinner, is mined by stripping. Here the bed has an average thickness of only 22 inches.

The Coalridge bed at Auburn, Ark., has been worked in local mines where its thickness is 18 inches and by stripping where it is as thin as 14 inches. So far as known, the minimum thickness worked commercially is 26 inches, at mines of the Enterprise Mining Company and Paris Coal Company at Paris, and the Ouita Coal Company at Mill Creek.

In the Southwestern region of Texas, which comprises a part of the Interior province, thin coal beds of Carboniferous age are mined. The thinnest of which any record has been obtained is $18\frac{3}{4}$ inches thick and is worked from a shaft 112 feet deep. At other places in Wise and Parker counties coal 19 and 20 inches thick is reported to be worked. In a report of the Geological Survey of Texas the following statement is made concerning the production from thin coal beds: "The production of coal in the Carboniferous area of Texas exceeds that of any other field of the State, and this, too, notwithstanding the very thin character of the coal seams."

Northern Great Plains province.—In the Northern Great Plains province thin beds are not mined to any considerable extent, probably for two reasons—the province is one in which thick deposits of low-grade coal predominate, and coal mining has been carried on for only a few years, except in the Great Falls field, where the industry is older and the coal is in some respects of better grade. In Yellowstone Valley, near Miles City, a low-grade subbituminous coal 3 feet 6 inches thick is worked—an exceptionally small thickness for a coal of this class.

Rocky Mountain province.—In the Rocky Mountain province coal mining can not be regarded as in an advanced stage of development and the mining of thin beds is not to be expected. However, at a number of scattered localities remarkably thin coal beds are mined. Of course, there is some exceptional condition which accounts for the mining of every thin coal worked throughout the West; but the experience of old and highly developed mining regions indicates that

such conditions will increase both in number and variety as time goes on.

In Montana the thinnest bed mined in a commercial way is probably the Eagle coal, 30 inches thick, at Bridger and Joliet, in the southern part of the State. The mine at Bridger, which is relatively large, was opened where the coal was thicker, and at a few places in the present workings the bed exceeds 30 inches in thickness. The coal obtained at Joliet, where the workings are on a smaller scale, is hauled 2½ miles in wagons. These two mines are located within 30 miles of the Red Lodge-Bear Creek coal field, the largest producing locality in Montana.

In Wyoming the mining of thin coals is rather exceptional, but a few cases may be noted. Near Saratoga, Carbon County, in the Larson mine, a bed of coal 16 inches thick is worked, and the product is hauled 12 miles in wagons to the town of Saratoga. This coal is mined in a region where thicker coals are near by. In the northern part of the Bighorn Basin coal 21 inches thick is mined locally for domestic use.

Near Newcastle, Garfield County, Colo., the Keystone mine operates in a commercial way under lease a bed of coal 20 to 24 inches thick. It is a high-grade bituminous coal and the mine is located near the railroad. Thicker coal beds are found near by. In Gunnison County the Floresta mine works a bed of anthracite coal which has a minimum thickness of 18 inches, though in places it reaches a thickness of 42 inches. The Enterprise mine, in El Paso County, Colo., in a region of much thicker coals, works a bed of subbituminous coal ranging in thickness from 30 to 42 inches. The output of this mine in 1906 was 5,798 tons. At the Starkville mine, in the Trinidad coal field, a bed of coal having a minimum thickness of 18 inches is worked; the average thickness of this bed, however, is considerably greater.

Very little mining of thin beds is carried on in New Mexico, but one case may be mentioned to illustrate how local conditions may influence the mining of thin beds. At the Cowles Coal Company's mine, Cowles, a bed of coal from 7 to 15 inches thick is worked to supply fuel for the Pecos Copper Company's mine located near by. This is the only coal anywhere near the copper mine, and for that reason it is probably a cheaper fuel than that shipped from a distance.

FACTORS AFFECTING THE MINING OF THIN COAL BEDS.

In any consideration of the subject of mining thin coal beds in the United States, a number of questions arise which should be taken into account even in so brief a treatment as that of the present paper. These are (1) the geologic or stratigraphic association of thin coal beds with thicker beds or those of approximately the same thickness; (2) the general quality of the coal found in the thin bed and the habit

of the bed itself, such as contained partings and soft material, either above or below the coal, which aids in mining; and (3) the effect of greater utilization of the heat value of the coal by the consumer.

In the first place, thin coal beds in this country, as elsewhere, are, as a rule, more or less intimately associated with thicker beds or occur in groups of beds of small dimension. It is rather exceptional to find an isolated thin coal bed at a great distance from other beds, and therefore the thin coal can generally be mined in conjunction with the thicker bed or with a group of beds of smaller thickness, as it is mined abroad. In quality the thinner coals are not necessarily inferior to the thicker ones, for a thin bed may represent simply a shorter period of coal deposition and not less favorable conditions. In fact, the Sewell and Blue Gem coal beds of West Virginia and Kentucky are the thinnest beds worked and at the same time among the best coals produced in those regions. The mining of a thin bed is thus mainly a matter of cost and is dependent on the price that can be got for the coal. One of the most important factors in bringing about the mining of thin coal beds and also of deep ones and at the same time preventing waste is the extraction of greater heat values from the coal used. A higher heat efficiency would permit consumers to pay an additional price for coal without increasing their fuel cost per unit of output. This in turn would make it possible for the producer to mine coals not only in thin beds but also at great depths. The additional cost would be met by the increased selling price. The practice of buying coal on a heat-producing basis, which is becoming more and more general, will indirectly stimulate the movement for obtaining greater heat value from coal in burning. If stronger emphasis is placed by the purchaser on the total heat contained in the fuel he uses, the producer can meet this demand only by grading his product or by interesting himself in bringing about the general use of improved appliances which will extract a greater efficiency from his coal, thereby creating a market for it. The selling of coal on a heat-producing basis will also lead to greater specialization in the use of fuel. One prominent English authority on this subject makes the following statement: "As time goes on much more of the inherent value of the coal will be taken from it and the method of the preparation of coal may have to be changed and improved to suit the different conditions under which coal may be used in the future." This is as true in the United States as in England.

STANDARDS ADOPTED FOR COAL LANDS OF THE PUBLIC DOMAIN.

In the classification of the coal lands remaining on the public domain the Director of the United States Geological Survey, with the approval of the Secretary of the Interior, has fixed 3,000 feet as the limit of depth of practical coal mining and 14 inches as the minimum thickness of a bed of coal which may be regarded as of workable dimension. The limit of depth chosen exceeds by only 800 feet the deepest coal beds which are actually being worked in this country and falls about 900 feet short of the depth at which coals are being successfully exploited in Belgium. It was clearly recognized in fixing this depth limit that 4,000 feet should be the limit consistent with present practice and experience in coal mining abroad. As the coals of the public lands, however, are in general of a medium grade and are located in the West, where their exploitation has only well begun, the time when coals on these lands lying between 3,000 and 4,000 feet below the surface would be worked is still remote. It was recognized that, under the present law, which does not permit the separation of surface and underground rights, the reservation of lands underlain by coals at these depths for mineral use only would prohibit the development of the surface features of such lands, which are of greater immediate value. The question became simply, For what use is the land most valuable? There was no doubt in the minds of those who fixed the depth limit of practical coal mining on the public domain at 3,000 feet that if the problem were considered in its broader aspect—that is, with a view to the future, in an endeavor to make the wisest disposition of the country's coal—the depth limit might properly be placed even at 4,000 feet.

In attempting to establish the minimum workable thickness of a coal bed it was hardly necessary, although very instructive, to look abroad for examples of thin-bed mining, for in parts of the Interior coal province of this country very thin coals are now worked. A minimum thickness of 14 inches does not seem extreme in any sense, as coal beds of this thickness are actually being worked by small mines in more than one locality in the Interior province and beds 2 to 4 inches thicker are being worked in several places by shipping mines of moderate size. This position is strengthened by the facts that in England and on the Continent coals considerably less than 14 inches thick are now being worked independently, and that for the last forty years, or since 1871, when the report of the first royal commission on coal supplies was made, 12 inches has been regarded in England as the minimum thickness of a workable coal bed.

The United States probably has greater coal resources than any other country and, as compared with England, has consumed a relatively small proportion of those resources; but these facts do not

justify the practice of disregarding coals as of no value which, by reason of their great depth or their occurrence in thin beds, are difficult to mine. Surely in the United States, which ranks first in the world's production, it would be possible to win coal under as great difficulties as in any other country.

Of course it is to be expected that the question of mining coals at great depth and in thin beds in a commercial way will be regarded by the practical coal-mining man of to-day as more or less speculative. This criticism may be justifiable in a measure if the subject is viewed only in the light afforded by present commercial practices; but if it is considered with the broader view which notes the marked changes in conditions that are already manifesting themselves—such as the progress in obtaining greater heat values from coals, the greater specialization of their uses, and the certain exhaustion of thicker, shallower, and more valuable beds—it is certainly reasonable to expect that deep and thin coals will some day be mined in this country in a commercial way, as they are at the present time in other countries, where the main difference in conditions is that coal exploitation has reached a more mature stage.

STATISTICS.

The following tables present in summarized form statistics on the maximum depth of coal mining and the minimum thickness of coal beds worked in the United States and in several foreign countries.

Statistics on depth of coal mining.

Locality.	Depth.	Quality of coal.	Reference.	Remarks.
England and Wales.				
Manchester:				
Pendleton colliery..	*Feet.* 3,483	.....	Dig. Evi. Roy. Com. Coal Supplies, 1901–1905, p. 74. Correspondence with A. S. E. Ackerman.	
Ashton Moss colliery—				
Shaft.....	2,790	.....	Trans. Inst. Min. Eng., vol. 21, 1900–1901, p. 67.	
Deepest workings.	3,360			
New Moss colliery, shaft.	2,820	.....	Dig. Evi. Roy. Com. Coal Supplies, 1901–1905, p. 74.	"At present the deepest shaft in the Kingdom."
New Moss colliery..	3,300	.....	.....do.....	Worked "a few years ago."
Bradford colliery...	2,550	.....	Idem, p. 73	
Yorkshire:				
Mine (name not given).	2,400	.....	.....do.....	
Mine (name not given).	2,130	.....	.....do.....	
Staffordshire:				
5 pits (names not given).	2,400–2,550	.....	Idem, p. 74	
Florence colliery...	2,400–2,700	.....	Idem, p. 75	
Lancashire: Agecroft colliery, Trencherbone mine.	2,940	.....	Idem, p. 74	

Statistics on depth of coal mining—Continued.

Locality.	Depth.	Quality of coal.	Reference.	Remarks.
England and Wales—Continued.				
Wigan:				
Alexandra pit—	*Feet.*			
Shaft	2,325	.....	Dig. Evi. Roy. Com. Coal Supplies, 1901–1905, p. 75.	
Deepest workings	2,700	.....	Dig. Evi. Roy. Com. Coal Supplies, 1901–1905, p. 75.	
Rosebridge colliery	2,445	.....	Trans. Inst. Min. Eng., vol. 21, 1900–1901, p. 67.	
Dunkinfield:				
Astley pit—				
Shaft	2,700	.....	do	
Deepest workings	3,150	.....	do	
Somerset: Kingswood colliery	2,460	.....	Dig. Evi. Roy. Com. Coal Supplies, 1901–1905, p. 75.	
Glamorgan, South Wales:				
Dowlais, Cardiff colliery	2,220	.....	Idem, p. 76	
Ocean collieries	2,700	.....	do	
Scotland.				
Portobello: Niddrie collieries	2,700	Cannel coal	do	
Australia.				
New South Wales: Sydney Harbor colliery, Birthday shaft	2,937	Bituminous coal.	Ann. Rept. Dept. Mines, New South Wales, 1902, p. 105. Idem, 1905, p. 111; 1906, p. 122.	Brick-lined shaft. The coal for which the Birthday shaft was sunk outcrops 75 miles away, at Newcastle, also on the coast and with equally good shipping facilities.
Belgium.				
Mons:				
Produits colliery	3,937	.....	Trans. Inst. Min. Eng., vol. 21, 1900–1901, p. 67.	
Produits colliery, Sainte Henriette shaft	3,773	.....	Correspondence with E. Lozé, Pas-de-Calais, France.	
Borinage:				
Agrappe No. 3	2,789	.....	do	
Agrappe No. 10	3,281	.....	do	
Mine No. 10 of Agrappe at Paturages—				
Hoisting shaft	3,330	.....	do	
Upcast shaft	3,445	.....	do	
Charleroi:				
Sacre Madame	2,641–3,461	.....	do	
Mine No. 11 of Marcinelle collieries—				
Downcast shaft	3,218	.....	do	
Upcast shaft	3,563	.....	do	
Montsur Marchienne of Marcinelle collieries—				
Downcast shaft	3,471	.....	do	
Upcast shaft	3,734	.....	do	
St. André shaft, Poirier colliery	3,150	.....	do	
Marchienne colliery	3,117	.....	Trans. Inst. Min. Eng., vol. 21, 1900–1901, p. 67.	
Anderlues: Viernoy shaft	3,300	.....	do	
Gilly: Viviers shaft	3,750	.....	do	
Average throughout Belgium	1,444	Gas coal to anthracite.	Correspondence with E. Lozé, Pas-de-Calais, France.	

Statistics on depth of coal mining—Continued.

Locality.	Depth.	Quality of coal.	Reference.	Remarks.
France.				
Nord: Dutemple pit of Anzin Co.	2,660	.....	Correspondence with E. Lozé, Pas-de-Calais, France.	Only depths over 800 meters (2,625 feet) here included. Article gives depths as low as 500 meters (1,640 feet).
Haute Saone:				
Arthur de Buyer mine of Ronchamps Association.	3,314	.....	.....do.....	
Eboulet mine.....	3,281	.....	.....do.....	
Loire: Plat-de-Gier.....	2,887	.....	.....do.....	
Gard: Salles-de-Gagnieres.	2,723	.....	.....do.....	
Germany.				
Near Chemnitz.....	2,952–3,117	.....	Correspondence with Dr. Hermann Wedding, Berlin, Germany.	
Rhenish-Westphalia: Dortmund.	2,625	.....	Dig. Evi. Roy. Com. Coal Supplies, 1901–1905, pp. 76–77.	
United States.				
Pennsylvania:				
Nanticoke, Anchiclass colliery.	2,200	Anthracite....	Correspondence with coal experts.	The greatest depth of bituminous coal mining in western Pennsylvania probably does not exceed 1,000 feet.
Ohio:				
Athens, Canaanville colliery.	439	Bituminous...	33d Ann. Rept. Insp. Mines, 1907, pp. 257–258.	The usual depth of coal mining in Ohio ranges from 40 to 250 feet.
West Virginia:				
Near Thurmond, Stewart Colliery Co.	a 630	.....do.....		
Kentucky:				
Jellico district.....	1,000	.....do.....	Correspondence with state geologist.	This depth is on the Blue Gem seam, a high-grade bituminous coal.
Tennessee.....	800	.....do	Consultation with persons familiar with the local conditions.	This depth may be regarded as the maximum for this State.
Alabama.....	600	.....do	.....	Maximum depth of coal mining in Alabama. Coal beds reach great depth in this State.
Michigan.....	250–300	.....do.....	.....	All coal mining in this State is at shallow depth.
Indiana:				
Oswald, Princeton Coal Mining Co.	450	.....do.....	Rept. State Min. Insp. 1906, p. 676; in 21st Ann. Rept. Dept. Geol. and Nat. Res.	Coal mining in Indiana ranges in depth from about 50 to 300 feet.
Illinois:				
Assumption, Assumption Coal Co.	1,003	.....do.....	Coal Rept. of Illinois, 1907, p. 140.	The output of this mine for 1907 was 83,959 tons. Coal mining in the State is generally shallow, ranging from a few feet to 300 feet.
Iowa:				
Albia, Hocking Coal Co. No. 3.	315	.....do	Correspondence with state geologist.	Usual depth of coal mining in Iowa ranges from 100 to 250 feet.
Missouri:				
Platte County, Home Riverside Coal Co.	720	.....do	21st Ann. Rept. Bur. Mines and Mine Insp., 1907, p. 258.	Coal mining in Missouri is usually shallow, ranging from 50 to 150 feet.
Arkansas:				
Russellville, Southern Anthracite Coal Co.	480	Semianthracite.	Bull. U. S. Geol. Survey No. 326, p. 105.	Average depth for State about 200 feet.

Statistics on depth of coal mining—Continued.

Locality.	Depth.	Quality of coal.	Reference.	Remarks.
United States—Con.				
Kansas:				
Atchison	1,170	Bituminous	Correspondence with state gologist.	Usual depth of coal mining in State ranges from 40 to 125 feet.
Oklahoma:				
Lehigh—				
Western Coal and Mining Co., mine No. 8.	684	do	Rept. Indian Territory Mine Insp., 1907, p. 12.	The deepest mining in Oklahoma occurs in the McAlester and Coalgate regions, 600 to 900 feet.
Missouri, Kansas and Texas Ry., coal department, mine No. 12.	865	do	Idem, p. 29	
Montana:				
Cokedale	1,300	Bituminous coking.		This mine is now abandoned. Coal mining in the Red Lodge and Great Falls fields, two of the largest in the State, does not exceed 500 to 600 feet in depth.
Wyoming:				
Cumberland	1,600	High-grade bituminous.		
Rock Springs, Union Pacific Coal Co., mine No. 1.	2,000			
Colorado:				
Starkville	1,100	Bituminous		
Carbondale, Spring Gulch mine.	1,500	Coking		
Glenwood Springs, South Canyon mine.	1,050	do		
Canyon City, Central mine.	1,087	Bituminous	Rept. State Mine Insp.	
Washington:				
Roslyn mine	700	do		
Oregon:				
Marshfield, Beaver Hill mine.	500	Subbituminous.		Deepest coal mine in State.
California:				
Stone Canyon	300	do		

[a] Shaft.

Land on the United States public domain which was underlain by coal at depths of 2,800, 4,100, 5,000, and 5,900 feet has been acquired from the Government by western coal companies because of its coal value, at a cost of $20 an acre.

A summary of opinions of several foreign authorities as to the maximum depth of practicable coal mining is given in the following table:

Opinions of foreign authorities on the possibilities of deep coal mining.

Country.	Depth, in feet.	Reference.	Remarks.
England and Wales....	4,000	Dig. Evi. Roy. Com. Coal Supplies, 1901-1905, p. 32.	Adopted as "the limit of practical depth in working" by the Royal Commission of 1871; again by the commission of 1901 and 1905.
Do.....	8,000	Trans. Inst. Min. Eng., vol. 21, 1900-1901, p. 67.	"It is probable that a depth of 8,000 feet will be attained."
Germany.....	3,608	Dig. Evi. Roy. Com. Coal Supplies, 1901-1905, pp. 76-77.	"The shafts which to-day are being worked at a depth of 700 to 800 meters [2,300 to 2,625 feet] will, at that period [twenty-five years], have reached the depth of 1,100 meters [3,608 feet]."
Do.....	4,921	Idem, p. 107.....	"The German miner has no doubt that not only is there a possibility, but the greatest likelihood, of pushing down to a depth of 1,500 meters [4,921 feet] or more, and of winning coal there at a comparatively profitable cost."
European Continent....	4,900	Correspondence with A. S. E. Ackerman, London.	"Experts on the Continent consider 4,900 feet about the limit of working."

Statistics on the mining of thin coal beds.

Locality.	Thickness in inches.	Depth in feet.	Quality of coal.	Reference.	Remarks.
England and Wales.					
East Lancashire.....	10	.....	Bituminous...	Roy. Com. Coal Supplies, vol. 1, p. 25.	These beds are worked independently and not in connection with thicker beds.
Do.....	10	.....	.....do.....	.....do.....	
Do.....	10	.....	.....do.....	.....do.....	
Do.....	11	.....	.....do.....	.....do.....	
Do.....	12	.....	.....do.....	.....do.....	
Do.....	12	.....	.....do.....	.....do.....	
Do.....	16	.....	.....do.....	.....do.....	
Do.....	16	.....	.....do.....	.....do.....	
Do.....	17	.....	.....do.....	.....do.....	
Do.....	18	300	Bituminous coking.	Idem, p. 27....	Coal in this mine is hauled 1,200 feet underground.
Do.....	18	.....	Bituminous...	Idem, p. 25....	
Do.....	18	.....	.....do.....	.....do.....	
Do.....	18	.....	.....do.....	.....do.....	
Lancashire, Lower Foot bed.	11	.....	.....do.....	Idem, p. 9.....	Bed worked near a larger mine of thicker coal.
Lancashire.....	8	900	Cannel.....	.....do.....	
Do.....	20-22	1,821	Bituminous...	Idem, p. 22....	
Shropshire, Westbury.....	14	300	.....do.....	Idem, p. 9.....	
Northeast Lancashire, Lower Mountain Mine bed.	12-18	.....	.....do.....	Idem, p. 13....	Attempt made to mine this seam commercially, but expense prohibited.
Yorkshire, Low Moor Better bed.	14	1,200	Coking.....	Idem, p. 16....	Men must be trained from boyhood to work in these thin beds.
Somerset, Bath, Braysdown colliery.	12	.....	.....	Idem, p. 32....	This seam worked in connection with six other beds averaging 17½ inches thick.
Somersetshire.....	22-26	2,400	.....	Idem, p. 35....	
Gloucester, Forest of Dean...	16	1,000	.....	Idem, p. 37....	This bed, in connection with four others, is being worked extensively.
South Wales coal field: Manmothshire, Tillery seam.	16	.....	Domestic and gas.	Idem, p. 38....	Output 100 tons a day. Bed worked separately, but in connection with a large concern.

Statistics on the mining of thin coal beds—Continued.

Locality.	Thickness in inches.	Depth in feet.	Quality of coal.	Reference.	Remarks.
England and Wales—Con.					
South Wales coal field—Con.					
Dowlais	21	400		Roy. Com. Coal Supplies, vol. 1, p. 39.	Twenty-seven men employed produced 12,690 tons a year, or 470 tons per man.
Scotland.					
Lanark and Stirling counties.	24–30	120–1,200		Idem, p. 20.	By virtue of adjacent rock strata this is a highly remunerative bed.
Do	15–20	120–1,200		Idem, p. 23.	Bed had been worked by hand, but not aggressively.
Do	15	120–1,200		do	This bed was regarded as of problematic workability.
Do	12	120–1,200		do	With exhaustion of thicker beds this might possibly be worked commercially.
East Scotland district:					
Coxrod coal, Westrigg colliery.	15			Idem, p. 26.	
Coxrod coal, Avonhead colliery.	13			do	
Upper Drumgray coal, Brownyside colliery.	14			do	
Lanarkshire and Stirlingshire, in Airdrie and Slamannon districts.	14–30	120–300		Idem, p. 29.	
Belgium.					
Hainaut coal basin:					
Flenu, colliery of Produits, Little French seam.	11		Rich gas	Idem, p. 41.	The seam is 15 inches thick and carries 11 inches of coal.
Quaregnon, colliery of Rieu du Cœur et de la Boule—					
Deux Haies bed	10.2			do	
Herlem bed	11			do	
Plate vein bed	12.6			do	
Sorciers bed	14			do	
Wasmes, colliery d'Hornu & Wasmes—					
Grand Gaillet bed	13.4		Lighting, gas	Idem, p. 42.	These coals are of excellent quality.
Grand Cornaillette bed.	13		do	do	
Georges bed	12.5		do	do	
Dour, Grande Machine à Feu de Dour, Deux Haies bed.	15.7		Coking	do	
Houdeng-Aimeries, colliery of Bois du Luc, St. Amand bed.	13		Domestic and coking.	do	
United States.					
Pennsylvania:					
Fourth bituminous district—					
Shawmut mine No. 5, Lower Kittanning bed.	[a] 26–34		Bituminous	Rept. State Min. Insp., 1907, p. 150.	Annual production, 76,765 tons.
Shawmut mine No. 6, Lower Kittanning bed.	[a] 26–34		do	do	Annual production, 41,084 tons.
Northwestern Mining and Exchange Co., Dagus No. 1, Lower Kittanning bed.	[a] 26–34		do	do	Annual production, 31,639 tons.
Western Clearfield district, Gassam mine.	17–48		do	Correspondence with acting state geologist.	

[a] These thicknesses are only for mines using mining machines.

Statistics on the mining of thin coal beds—Continued.

Locality.	Thickness in inches.	Depth in feet.	Quality of coal.	Reference.	Remarks.
United States—Continued.					
West Virginia:					
Fayette County, Sewell, Longdale Coal and Iron Co., Sewell bed.	20–24	[a] 500–600	High-grade bituminous.	Correspondence with state geologist.	Not worked at present.
McDowell County, Helena Coal Co., Pocahontas thin bed.	24–36	.....	Bituminous...	22d Ann. Rept. State Min. Insp. Coal Mines, 1904, p. 269.	
Mingo County, Nolan Coal Co., Kittanning bed.	24–36	.....	.....	Idem, p. 276...	
Maryland:					
Morrisons, Frostburg Coal Mining Co.	30	.....	Semibituminous.	State Geol. Rept., vol. 5, p. 343.	
Ohio:					
Jackson County—					
Jackson, Superior Coal Co., Superior No. 12 bed.	28	[a] 150	Bituminous...	33d Ann. Rept. Insp. Mines, 1907, p. 215.	
Price Switch—					
See Kay Coal Co., See Kay mine.	30	(b)	.....do.....	Idem, p. 217...	
Tibbals Coal Co., Tibbal's mine No. 2.	26	(b)	.....do.....	Idem, p. 219...	This mine has recently been abandoned.
W. A. Gosline & Co., Price mine.	26	(b)	.....do.....	Idem, p. 221...	
Byers, Woods & Brown Coal Co., Buckeye mine No. 2.	28	(b)	.....do.....	Idem, p. 220...	
Jackson—					
Henry Holberg mine.	26	(b)	.....do.....	33d Ann. Rept. Insp. Mines, 1907, p. 221.	Mine now abandoned.
Henry Holberg mine No. 4.	26	(b)	.....do.....	Idem, p. 228...	
Oak Hill, Oak Hill Fire Brick Co., Oak Hill F. B. Mine.	26	(b)	.....do.....	Idem, p. 222...	
Crescent Coal Co., Crescent mine.	28	(b)	.....do.....	Idem, p. 223...	
Coalton, Henry Pritchard mine.	28	(b)	.....do.....	.....do.....	Mine in poor condition.
W. J. Rowe & Son, Rowe mine.	28	(b)	.....do.....	Idem, p. 224...	
Sun Coal Co., Sun mine.	28	(b)	.....do.....	Idem, p. 227...	
Vinton County, Inghams, Valley Coal Co., Inghams mine.	28	(b)	.....do.....	Idem, p. 228...	
Mahoning County, McDonald Brothers, Five Point mine, 3-A seam.	28	[a] 74	.....do.....	Idem, p. 385...	
Kentucky:					
Jellico field—					
Blue Gem bed.....	24	.....	High-grade bituminous.	Rept. State Min. Insp., 1901–2, p. 292.	It has been reported from a reliable source that 10,000 acres which was known from prospect holes to be underlain by this bed with an average thickness of 22 inches was leased for coal-mining purposes. Coal in demand for domestic use. Blue Gem seam, 20 inches thick, has been mined with profit.
Mine.....	22	.....	.....do.....	.....	

[a] Shaft. [b] Drift.

Statistics on the mining of thin coal beds—Continued.

Locality.	Thickness in inches.	Depth in feet.	Quality of coal.	Reference.	Remarks.
United States—Continued.					
Tennessee:					
Campbell County, Newcomb, Big Italian mine.	22	.....	High-grade bituminous.	17th Ann. Rept. Min. Dept., 1907, p. 39.	
Indiana:					
Clay County—					
Crawford Coal Co., Crawford No. 8 mine.	36	50	Block.....	Rept. State Min. Insp., 1906, p. 674, in 21st Ann. Rept. Dept. Geology and Nat. Res., 1906.	This is an average thickness of the coal actually being mined. The lower "block" averages a little under 3 feet and the upper "block" a little over. Wage scale for this field is based on thickness of bed. Cost becomes prohibitive at about 28 inches.
Brazil—					
Indiana Block Coal Co., Lower Vein No. 1 mine.	36	58	.....do.....	.....do.....	
Vandalia Coal Co., Vandalia No. 50 mine.	36	105	.....do.....	.....do.....	
Alabama:					
Dekalb County, Lahusage, Lookout Fuel Co.	22-24	.....	.....	Rept. Insp. Alabama Coal Mines, 1908, p. 14.	78 men employed.
Illinois:					
Knox County—					
Abingdon—					
James Tell mine.	22	(a)	Bituminous...	Coal Rept. of Illinois, 1905, p. 158.	Annual output 240 tons.
William Carson mine.	22	(a)	.....do.....	.....do.....	Annual output 200 tons.
James Cross mine	22	(a)	.....do.....	.....do.....	Annual output 80 tons.
Sam Nelson mine	24	(b)	.....do.....	Idem, 1907, p. 145.	Annual output 1,350 tons.
Pointer & Cross mine.	24	(a)	.....do.....	.....do.....	Annual output 1,000 tons.
William Courson mine.	24	(a)	.....do.....	.....do.....	Annual output 700 tons.
Warren County—					
Monmouth—					
Thos. A. Welch mine.	24	(a)	.....do.....	Idem, 1905, p. 175.	Annual output 1,200 tons.
George Menifield mine.	24	c40	.....do.....	Idem, 1907, p. 160.	Annual output 2,400 tons.
Roseville, J. B. Russell mine.	22	c32	.....do.....	Idem, 1905, p. 175.	Annual output 720 tons.
Prairie City, G. W. Franklin mine.	22	(a)	.....do.....	.....do.....	Annual output 266 tons.
Youngstown, Thomas Lee mine.	22	(b)	.....do.....	.....do.....	Annual output 200 tons.
Avon, William Ruhl mine.	20	(b)	.....do.....	.....do.....	Annual output 48 tons.
Shelby County—					
Shelbyville, John Anglin mine.	26	c64	.....do.....	Idem, 1907, p. 156.	Annual output 2,000 tons.
Shelbyville.....	17	(c)	.....do.....	.....do	
Michigan:					
Saginaw County, Saginaw mine.	26	.....	.....do	Correspondence with Consolidated Coal Co.	
Do.....	24	.....	.....do.....	.....do	This is the minimum thickness of coal mined in a commercial way in Michigan.

a Drift. b Slope. c Shaft.

Statistics on the mining of thin coal beds—Continued.

Locality.	Thickness in inches.	Depth in feet.	Quality of coal.	Reference.	Remarks.
United States—Continued.					
Missouri:					
Jackson County, Brush Creek Coal Co. mine.	18	a 320	Bituminous..	Rept. State Min. Insp., 1902, p. 125.	This mine employs 60 men.
Barton County—					
Joseph Bradley mine	12	(b)	.....do.....	19th Ann. Rept. Bur. Mines, 1905, p. 249.	80 acres leased. Capital invested in equipment, $2,500.
W. M. Peck mine...	12	(b)	.....do.....	.....do.....	
Peck & Brunnett mine.	12	(b)	.....do.....	21st Ann. Rept. Bur. Mines, 1907, p. 132.	Annual output, 104 tons. Local.
Carroll County, Howard Kingslow mine.	18	a 50	.....do.....	Idem, p. 164..	
Chariton County, John Davis mine.	17	(b)	.....do.....	.....do.....	Annual output, 160 tons.
Clay County, Missouri City Coal Co. mine.	20	a 106	.....do.....	.....do.....	Annual output, 40,590 tons. Capitalization of mine, $10,000.
Grundy County—					
Trenton Mining Co. mine.	19	a 240	.....do.....	Idem, p. 184...	Annual output, 11,040 tons. Capitalization of mine, $30,000.
Howard County, R. S. Jackson mine.	18	(b)	.....do.....	.....do.....	Annual output 522 tons.
Lafayette County—					
Diamond Coal Co. mine.	18	a 56	.....do.....	Idem, p. 214...	Annual output 49,786 tons. Capitalization of mine $10,000.
Farmers' Coal Co. mine.	19	a 55	.....do.....	.....do.....	Annual output 37,600 tons. Capitalization of mine, $150,000.
Kierstead Coal Co. mine.	18	a 90	.....do.....	.....do.....	Annual output 18,176 tons. Capitalization of mine, $50,000.
Laning-Harris C. & G. Co. mine.	18	(b)	.....do.....	.....do.....	Annual output 27,534 tons. Capitalization of mine, $127,600.
Labor Exchange, No. 305, mine.	18	a 93	.....do.....	.....do.....	Annual output 11,649 tons. Capitalization of mine, $10,000.
Thomas Perry mine.	16	(b)	.....do.....	.....do.....	Annual output, 385 tons.
W. Tyler mine.....	16	a 24	.....do.....	.....do.....	Annual output, 485 tons.
Fred Walters mine..	16	(b)	.....do.....	.....do.....	Annual output, 900 tons.
L. M. Manning mine.	14	(b)	.....do.....	19th Ann. Rept. Bur. Mines, 1905, p. 257.	Small mine.
Strother Brothers mine.	14	(c)	.....do.....	.....do.....	
J. A. Williamson mine.	16	(c)	.....do.....	Idem, p. 258...	Capitalization of mine, $2,100.
N. F. Wilson mine...	14	(b)	.....do.....	.....do.....	
Livingston County, Geo. T. Walters mine.	15	a 51	.....do.....	21st Ann. Rept. Bur. Mines, 1907, p. 240.	Annual output, 260 tons.
Nodaway County—					
Claypool & England mine.	15	a 58	.....do.....	Idem, p. 258...	Annual output, 120 tons.
William Bird mine..	12	a 28	.....do.....	19th Ann. Rept. Bur. Mines, 1905, p. 260.	
L. E. Bridge mine...	16	a 27	.....do.....	.....do.....	
A. Collins mine.....	12	a 44	.....do.....	.....do.....	
Fred Pierson mine...	14	a 22	.....do.....	.....do.....	

a Shaft. b Drift. c Slope.

Statistics on the mining of thin coal beds—Continued.

Locality.	Thickness in inches.	Depth in feet.	Quality of coal.	Reference.	Remarks.
United States—Continued					
Missouri—Continued.					
Nodaway County—Con.					
Al Russell mine.....	12	a 35	Bituminous ..	19th Ann. Rept. Bur. Mines, 1905, p. 260.	
Ray County—					
Samuel Benware mine.	16	(b)	.....do.....	21st Ann. Rept. Bur. Mines, 1907, p. 282.	Annual output, 168 tons.
G. C. & A. B. Brockman mine.	16	a 30	.....do.....	.....do.....	Annual output, 176 tons. Capitalization, $400.
James Love mine....	16	(b)	.....do.....	Idem, p. 283...	Annual output, 205 tons.
Kansas:					
Weir-Pittsburg region...	18–24	.....	.....	.....	This is the minimum thickness reported by some of the mines in the Weir-Pittsburg region, which is the largest coal-mining field in Kansas.
Leavenworth district....	24	a 720	.....	Univ. Geol. Survey Kansas, vol. 3, p. 155.	This coal is mined by stripping and by drifts and shafts, and is of sufficiently high grade to compete successfully with the Weir-Pittsburg coal.
Arcadia region, Arcadia, Kansas.	20			Idem, p. 178...	
Osage City region.....	15–18	a 30	.....	Idem, p. 191...	These are small mines, or country banks.
Do.....	20–22				
Oklahoma:					
Melvin.....	22	(c)	Bituminous...	Geol. Atlas U. S., folio 132, 1906, p. 6.	Local consumption only.
Arkansas:					
Ouachita County—					
Camden—					
Dempsey mine..	36	(d)	Lignite.....	21st Ann. Rept. U. S. Geol. Survey, pt. 2, 1900, p. 323.	
Bratt mine.....	36	a 40	.....do.....	Idem, p. 324...	
Dyer mine (sec. 21, T. 10 N., R. 29 W.).	12	.....	Semibituminous.	Bull. U. S. Geol. Survey No. 326, 1907, p. 129.	Coal removed by stripping the surface. Abandoned at present.
Sebastian County—					
Auburn—					
Coalridge bed (sec. 20, T. 7 N., R. 29 W.).	18	.....	Bituminous...	Idem, p. 130...	Local mine.
Paris bed (sec. 27, T. 7 N., R. 29 W.).	14	.....	.....do.....	.....do.....	Coal removed by stripping the surface.
Franklin County—					
Charleston, Charleston bed (sec. 16, T. 7 N., R. 28 W.).	18	.....	.....do.....	Idem, p. 131...	Formerly worked, but now abandoned.
Ozark, Philpott mine (sec. 20, T. 10 N., R. 25 W.).	22	.....	.....do.....	Idem, p. 137...	Local mine.
Logan County—					
Paris—					
Enterprise Mining Co. mine (sec. 1, T. 7 N., R. 26 W.).	26	.....	Semibituminous.	.....do.....	Shipping mine.
Paris Coal Co. mine (sec. 10, T. 7 N., R. 26 W.).	26	.....	.....do.....	.....do.....	Do.

a Shaft. b Drift. c Stripping. d Slope.

Statistics on the mining of thin coal beds—Continued.

Locality.	Thickness in inches.	Depth in feet.	Quality of coal.	Reference.	Remarks.
United States—Continued.					
Arkansas—Continued.					
Pope County, Milcreek, Ouita Coal Co. mine (sec. 20, T. 8 N., R. 20 W.).	26	.....	Semianthracite.	Bull. U. S. Geol. Survey No. 326, 1907, p. 148.	Shipping mine.
Texas:					
Webb County, San Thomas mine.	30	.....	Subbituminous.	Geol. Survey Texas, p. 189.	
Wise County—					
Wise County Coal Co.	20	[a] 55	Bituminous...	Tex. Univ. Min. Survey, Bull. 3, p. 34.	
Bridgeport—					
Bridgeport Coal Co. mine No. 1.	19	[a] 56	Subbituminous.	.....do.....	
Bridgeport Coal Co. mine No. 2.	19⅔	[a] 112	.....do.....	Idem, p. 35....	
Parker County, Rock Creek, Texas Coal and Fuel Co. mine No. 1.	21	[a] 150	.....do.....	.....do.....	
Iowa:					
Taylor County—					
Union Coal Co., Nodaway bed.	14–18	[a] 70–187	Low-grade bituminous.	Rept. State Min. Insp., 1908, pp. 10, 42.	
Campbell Coal Co., Nodaway bed.	14–18	[a] 70–187	.....do.....	.....do.....	Three of these are shipping mines and three local. Combined output 1908, 13,861 tons.
William Browning Co., Nodaway bed.	14–18	[a] 70–187	.....do.....	.....do.....	
Campbell Coal Co. No. 2, Nodaway bed.	14–18	[a] 70–187	.....do.....	.....do.....	
Easter Coal Co., Nodaway bed.	14–18	[a] 70–187	.....do.....	.....do.....	
Luellen Coal Co., Nodaway bed.	14–18	[a] 70–187	.....do.....	.....do.....	
Page County—					
Johnson & Co., Nodaway bed.	14–18	[a] 70–230	.....do.....	.....do.....	
Pierson & Marley, Nodaway bed.	14–18	[a] 70–230	.....do.....	.....do.....	Local mines. Combined output 14,045 tons.
J. Marshall, Nodaway bed.	14–18	[a] 70–230	.....do.....	Idem, pp. 10, 44.	
Coin Coal Co., Nodaway bed.	14–18	[a] 70–230	.....do.....	.....do.....	
Adams County—					
Jones, Nodaway bed.	14–18	[a] 70–230	.....do.....	Idem, pp. 10, 46.	
Ruth, Nodaway bed.	14–18	[a] 70–230	.....do.....	.....do.....	
Wild, Nodaway bed.	14–18	[a] 70–230	.....do.....	.....do.....	
Day, Nodaway bed..	14–18	[a] 70–230	.....do.....	.....do.....	
Hathaway, Nodaway bed.	14–18	[a] 70–230	.....do.....	.....do.....	
Smith & Tindall, Nodaway bed.	14–18	[a] 70–230	.....do.....	.....do.....	Local mines. Combined output 17,760 tons.
Smith & Dixon, Nodaway bed.	14–18	[a] 70–230	.....do.....	.....do.....	
Demirjean, Nodaway bed.	14–18	[a] 70–230	.....do.....	.....do.....	
Daugherty & Son, Nodaway bed.	14–18	[a] 70–230	.....do.....	.....do.....	
Weil, Nodaway bed..	14–18	[a] 70–230	.....do.....	.....do.....	
Montana:					
Carbon County—					
Joliet, Barrett Brothers, Bergin mine.	30	.....	Subbitumi-nous.	Bull. U. S. Geol. Survey No. 341, 1909, p. 193.	Coal hauled in wagons about 2½ miles.
Bridger, Bridger Coal Improvement Co., Bridger mine.	30–68	.....	.....do.....	Idem, p. 189...	This mine was opened on thicker coals, and in certain parts of the present workings the thickness exceeds 30 inches. Commercial mine.

[a] Shaft.

Statistics on the mining of thin coal beds—Continued.

Locality.	Thickness in inches.	Depth in feet.	Quality of coal.	Reference.	Remarks.
United States—Continued.					
Montana—Continued.					
Custer County, Miles City, Brown's mine.	42	.....	Low-grade subbituminous.	Bull. U. S. Geol. Survey No. 341, 1909, p. 50.	
Wyoming:					
Carbon County, Saratoga, Larson mine.	16	.....	Bituminous...	Bull. U. S. Geol. Survey No. 316, 1907, p. 247.	This coal is hauled by wagon 12 miles to the town of Saratoga. Thicker coals near by.
Bighorn County, Byron, mine.	21	.....	Subbituminous.	Bull. U. S. Geol. Survey No. 341, 1909, p. 180.	Mined locally for domestic use.
Colorado:					
Garfield County, Newcastle, Dalrymple & Meese, Keystone mine (worked under lease).	20–24	[a] 500	High-grade bituminous.	Bull. U. S. Geol. Survey No. 316, 1907, p. 290.	Commercial mine. Worked because coal is located on the railroad and is of a superior quality. Production in 1908 was 6,348 tons. Thicker coals located near by.
El Paso County, Enterprise mine.	30–42	[b]	Lignite.....	Rept. Coal Min. Insp., 1905–6, p. 17.	This coal is located near beds ranging from 5 to 17 feet in thickness. Production in 1906 was 5,798 tons.
Montezuma County, mine.	30	[c]	.....do.....	Idem, 1907, p. 60.	Production in 1907, 150 tons; in 1908, 441 tons.
Gunnison County, Floresta mine.	18–42	[c]	Anthracite....	Idem, 1905–6, p. 22.	
Las Animas County, Starkville mine.	18–84	[c]	Bituminous...	Idem, p. 28...	Production, 315,906 tons.
La Plata County, Durango, Todd & Bolster, Todd mine.	28–30	.....	Subbituminous.	Bull. U. S. Geol. Survey No. 316, 1907, p. 389.	This is reported to be the thinnest coal bed mined in the San Juan coal basin.
New Mexico:					
San Miguel County, Cowles, Cowles Coal Co., mine.	7–15	.....	.....do.....	.....	This coal is mined to supply fuel to the Pecos Copper Co.'s mine, which is located near by. There are no thicker beds of coal near this mine.

[a] Slope. [b] Shaft. [c] Drift.