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COAL RESOURCES OF THE UNITED STATES

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By

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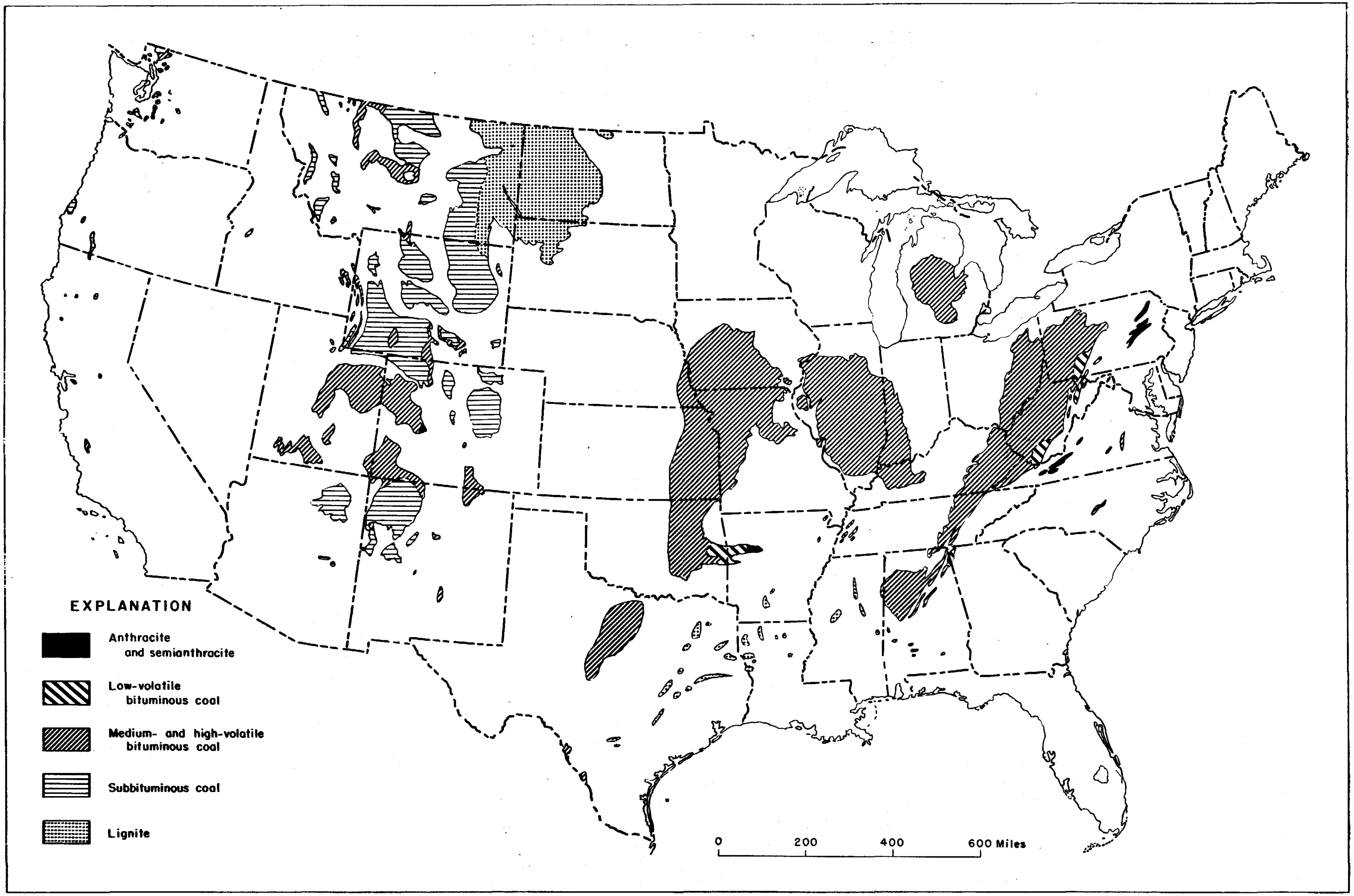

Figure I. - Coal fields of the United States.

COAL RESOURCES OF THE UNITED STATES

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INTRODUCTION

Interest in the quantity and quality of the coal reserves of the United States has increased greatly since the end of World War II, principally because of the growing realization that the ultimate reserves of petroleum and natural gas, although largely undefined, still have finite limits. With the greatly increased use of petroleum and natural gas, it has become further apparent that the reserves of these two fuels, whatever their ultimate limits may prove to be, are being consumed at a rate far surpassing that anticipated a few years ago. At some time in the future, therefore, the contribution of coal to the total production of energy in this country must inevitably be enlarged to include some of the needs now served by petroleum and natural gas.

Although coal-bearing rocks cover 14 percent of the total area of the United States (fig. 1) and contain enormous reserves, it is equally apparent that reserves of coal also have limits. In the extensively mined sections in the East it is already increasingly difficult to locate new areas containing thick beds of high-rank and high-quality coal to replace areas that have been mined out. Furthermore, a considerable part of the total reserves of the United States consists of coal of lignite and subbituminous ranks and coal contained in thin beds that can be mined only with great difficulty and expense. At the present time, therefore, the depletion of reserves of high-rank and high-quality coal, particularly the Eastern coal that is suitable for the manufacture of metallurgical coke, is a more serious problem than the percentage depletion of the total coal reserves.

Recognizing the need for more detailed estimates of coal reserves than those that have been available in the past, the U. S. Geological Survey is now preparing a reappraisal of the coal reserves of the United States in which primary emphasis is placed on the amounts of coal in separate categories according to rank, thickness of coal, and thickness of overburden. Many of the state geological surveys in coal-producing areas are also preparing new appraisals of coal reserves. The increasing volume of geologic data available on the occurrence of coal and the detailed and careful methods now employed in calculating reserves should ultimately provide a more reliable estimate for the coal reserves of the United States than has been obtainable previously, although much additional work remains to be done.

According to the information currently available, the total coal reserves of the United States remaining in the ground on January 1, 1950, are 2,425,566 million tons, which are divided by rank as follows:

Remaining coal reserves of the United States, January 1, 1950

Rank	Estimated total reserves remaining in the ground, January 1, 1950 (In millions of short tons)	Estimated recoverable reserves, January 1, 1950, assuming 50 percent recovery	
		(In millions of short tons)	(In quadrillions of B. t. u.)
Bituminous coal.....	1,232,635	616,318	16,024
Subbituminous coal ..	467,700	233,850	4,443
Lignite	711,451	355,725	4,767
Anthracite and semianthracite...	13,780	6,890	175
Total.....	2,425,566	1,212,783	25,409

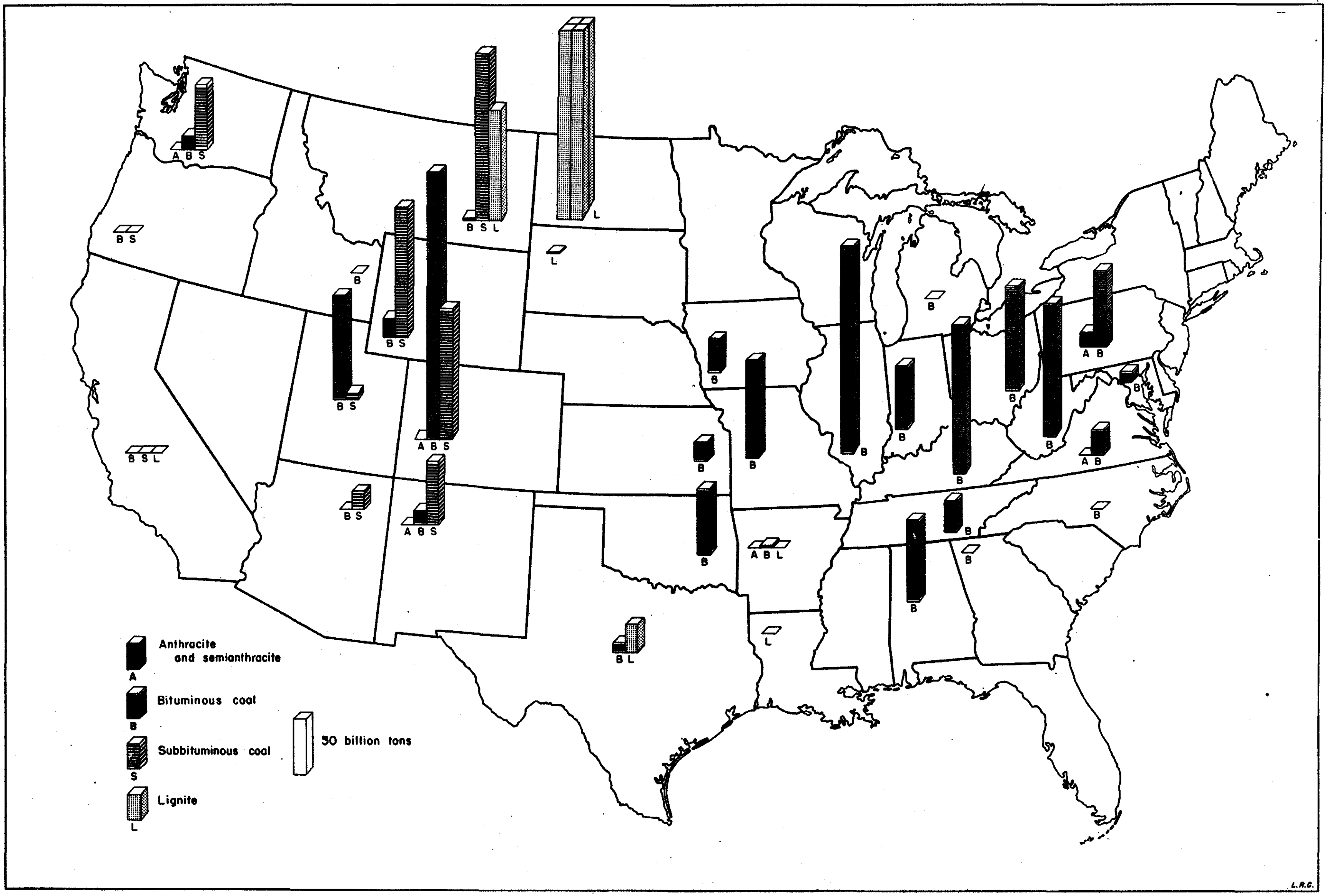

Figure 2. - Remaining coal reserves of the United States, January 1, 1950

These totals, which are somewhat less than the previous, widely quoted estimates of M. R. Campbell of the U. S. Geological Survey, are based on new appraisals of coal reserves in Michigan, Montana, New Mexico, North Carolina, and Wyoming, prepared since 1948 by the U. S. Geological Survey; on appraisals of reserves in Illinois, Kansas, Missouri, Pennsylvania, and West Virginia, prepared by the geological surveys of those States;and on the older estimates of Campbell for the remaining states. Both for past and for estimated future losses in mining, the more realistic figure of 50 percent has been used, instead of the figure of 34.7 percent derived in 1923 by the U. S. Bureau of Mines for the U. S. Coal Commission (Rice and Paul, 1923) and used in preparing most of of the previous estimates of the U. S. Geological Survey.

PREPARATION OF COAL-RESERVE ESTIMATES

All estimates of coal reserves are based largely on detailed geologic maps showing the outcrops and correlations of the individual coal beds and on accompanying geologic reports giving detailed measurements of the coal thickness. This information is augmented locally by data from exploratory and development drilling. Unfortunately, many coal-bearing areas in the United States have not been mapped geologically; many others have been mapped only in reconnaissance; and few have been prospected other than along the outcrops of the beds. Progress toward full knowledge of the coal reserves of the United States depends, therefore, upon an active program of detailed geologic mapping and exploratory drilling. Such detailed work is in progress on a modest scale by the U. S. Geological Survey and several State agencies.

The U. S. Geological Survey is also preparing summary appraisals of coal reserves by states. All the published information on the thickness and extent of coal beds, together with unpublished data contained in the files of the U. S. Geological Survey and State surveys and data from mining and drilling companies, is used as a basis for these summary estimates. The reserve figures are classified according to rank and thickness of coal, thickness of overburden, and abundance of reliable information concerning the presence of coal at a distance from mines, drill holes, or outcrops. The reserve estimates for Michigan, Montana, New Mexico, North Carolina, and Wyoming have been presented previously in separate detailed publications. These studies, together with available reserve estimates published by the State geological surveys of Illinois, Kansas, Missouri, Pennsylvania, and West Virginia, provide the basis for the provisional tables included in this circular. (See tables 1 and 2 and fig. 2.) For other states, where little or no detailed summary work on coal reserves has been carried on, the estimates used in the new provisional tables are those of M. R. Campbell as reprinted by Hendricks and others. (Hendricks, 1939; Buch, Hendricks, and Toenges, 1947). It should be noted that the Campbell estimates were made on a more generous basis than the recent estimates and, although appearing in the same tables, are not directly comparable. To alter these figures arbitrarily by some purely mathematical method for use in this progress report would be unnecessarily confusing, however, particularly in view of the fact that the revision of certain of these state estimates is now in progress by the Geological Survey.

Estimates of coal reserves based on information currently available are inevitably only provisional estimates and are subject to change as mapping, prospecting, and development are continued.

At the present stage of knowledge, therefore, estimates of coal reserves must be based on many assumptions as to the thickness, extent, and correlation of the coal beds and other pertinent factors. These factors are described in the following paragraphs as a basis for explaining the points of similarity and difference between the estimates of reserves in different states presented in the accompanying tables.

RANK OF COAL

Coal is classified by rank according to percentage of fixed carbon and B. t. u. content. As shown in figure 3, the percentage of fixed carbon and the B. t. u. content, except in anthracite, increase from the lowest to the highest rank of coal as the percentages of volatile matter and moisture decrease. The reduction of volatile matter and moisture and the accompanying increase in fixed carbon took place progressively during the process by which plant material deposited in swamps and marshes in the geologic past was transformed into coal. The lower layers of plant material in the swamps were first compacted under successive layers of vegetation. Later, as the sea covered the coal swamps, the accumulated weight of sediments deposited on the sea floor further compressed the plant material and caused successive reductions in the amounts of volatile matter and moisture. Locally, deformation of the coal-bearing sediments by movements of the earth's crust also aided in the process of coalification. The ranks of coal--lignite, subbituminous coal, bituminous coal, and anthracite--represent successive stages in the formation of coal.

The standard classification of coal by rank in use in the United States is that established by the American Society for Testing Materials (1939). This classification, which is reproduced on page 7, is used uniformly in classifying all coal-reserve estimates. As coals of different rank are adaptable to different uses, rank is the major basis of differentiation shown in figures 1 and 2 and in tables 1 and 2.

ORIGINAL, REMAINING, AND RECOVERABLE RESERVES

The coal reserves shown in tables 1 and 2 are further classified as original reserves, remaining reserves, and recoverable reserves. Original reserves are reserves of coal in the ground before the beginning of mining operations. In the calculation of original reserves no allowance is made for past production and losses in mining or for future losses. Remaining reserves are reserves in the ground as of the date of appraisal and are obtained by subtracting past production and losses from original reserves. Recoverable reserves are reserves of coal in the ground as of the date of appraisal that can actually be produced in the future and are obtained by subtracting estimated future losses in mining from the remaining reserves.

The preparation of an estimate of original reserves is essential to the successful determination of remaining and recoverable reserves because it provides a base figure from which other figures can be derived. An estimate of original reserves, although subject to

Table 1.--Coal reserves of the United States, January 1, 1950, by rank
(In thousands of short tons)

State	Estimated original reserves	Reserves depleted to January 1, 1950		Remaining reserves, January 1, 1950	Recoverable reserves, January 1, 1950, assuming 50-percent recovery
		Produced 1/	Produced and lost in mining, assuming past losses equal production		
BITUMINOUS COAL					
Alabama	67,570,000	821,590	1,643,180	65,926,820	32,963,410
Arkansas	1,396,000	82,785	165,570	1,230,430	615,215
Colorado	213,071,000	357,719	715,438	212,355,562	106,177,781
Georgia	933,000	11,533	23,066	909,934	454,967
Illinois	171,905,000	3,131,997	6,263,994	165,641,006	82,820,503
Indiana	53,051,000	984,137	1,968,274	51,082,726	25,541,363
Iowa	29,160,000	343,162	686,324	28,473,676	14,236,838
Kansas	2/ 17,574,000	3/ 9,800	3/ 19,600	17,554,400	8,777,200
Kentucky	123,327,000	1,951,803	3,903,606	119,423,394	59,711,697
Maryland	8,043,000	259,943	519,886	7,523,114	3,761,557
Michigan	296,900	4/ 46,240	5/ 77,000	219,900	109,950
Missouri	79,362,016	257,787	515,574	78,846,442	39,423,221
Montana	2,362,610	31,491	62,982	2,299,628	1,149,814
New Mexico	10,947,700	88,189	176,378	10,771,322	5,385,661
North Carolina ...	110,462	1,054	2,108	108,354	54,177
Ohio	86,497,000	1,694,259	3,388,518	83,108,482	41,554,241
Oklahoma	54,951,000	158,846	317,692	54,633,308	27,316,654
Pennsylvania	75,093,459	7,416,956	14,833,912	60,259,547	30,129,774
Tennessee	25,665,000	324,718	649,436	25,015,564	12,507,782
Texas	8,000,000	10,706	21,412	7,978,588	3,989,294
Utah	88,184,000	195,833	391,666	87,792,334	43,896,167
Virginia	21,149,000	538,887	1,077,774	20,071,226	10,035,613
Washington	11,413,000	123,804	247,608	11,165,392	5,582,696
West Virginia	116,618,447	4,979,385	9,958,770	106,659,677	53,329,838
Wyoming	13,234,950	230,272	460,544	12,774,406	6,387,203
Other states 6/ ..	820,000	4,956	9,912	810,088	405,044
Total	1,280,735,544	24,057,852	48,100,224	1,232,635,320	616,317,660
SUBBITUMINOUS COAL					
Colorado	104,175,000	107,506	215,012	103,959,988	51,979,994
Montana	132,151,060	124,544	249,088	131,901,972	65,950,986
New Mexico	50,801,200	32,226	64,452	50,736,748	25,368,374
Utah	5,156,000	2,832	5,664	5,150,336	2,575,168
Washington	52,442,000	19,100	38,200	52,403,800	26,201,900
Wyoming 8/........	108,318,900	132,103	264,206	108,054,694	54,027,347
Other states 7/ ..	15,500,000	3,832	7,664	15,492,336	7,746,168
Total	468,544,160	422,143	844,286	467,699,874	233,849,937
LIGNITE					
Arkansas	90,000	0	0	90,000	45,000
Montana	87,533,270	1,213	2,426	87,530,844	43,765,422
North Dakota	600,000,000	67,856	135,712	599,864,288	299,932,144
South Dakota	1,020,000	921	1,842	1,018,158	509,079
Texas	23,000,000	51,341	102,682	22,897,318	11,448,659
Wyoming 8/	---	---	---	---	---
Other states 9/ ..	49,963	1	2	49,961	24,981
Total	711,693,233	121,332	242,664	711,450,569	355,725,285
ANTHRACITE AND SEMIANTHRACITE					
Arkansas	230,000	9,109	18,218	211,782	105,891
Colorado	100,000	5,921	11,842	88,158	44,079
New Mexico	5,700	1,092	2,184	3,516	1,758
Pennsylvania	22,805,000	4,916,006	9,832,012	12,972,988	6,486,494
Virginia	500,000	9,592	19,184	480,816	240,408
Washington	23,000	0	0	23,000	11,500
Total	23,663,700	4,941,720	9,883,440	13,780,260	6,890,130
Total, all ranks .	2,484,636,637	29,543,047	59,070,614	2,425,566,023	1,212,783,012

1/ Production, 1800 through 1885, from The first century and a quarter of American coal industry, by H. N. Eavenson, privately printed, Pittsburgh, 1942; production, 1886 through 1949, from U. S. Bureau of Mines Minerals Yearbooks, unless otherwise indicated.

2/ Remaining reserves, January 1, 1946.

3/ Production, January 1, 1946, to January 1, 1950.

4/ Michigan Geological Survey Division, as cited in U. S. Geological Survey Circular 77, p. 56, 1950.

5/ Past losses assumed to be 40 percent of coal originally in the ground.

6/ Includes Arizona, California, Idaho, and Oregon.

7/ Includes Arizona, California, and Oregon.

8/ Small reserves and production of lignite included under subbituminous coal.

9/ Includes California and Louisiana.

Table 2.--Coal reserves of the United States, January 1, 1950, by states
(In thousands of short tons)

State	Estimated original reserves					Reserves depleted to January 1, 1950		Remaining reserves, January 1, 1950	Recoverable reserves, January 1, 1950, assuming 50-percent recovery
	Bituminous coal	Subbituminous coal	Lignite	Anthracite and semianthracite	Total	Produced 1/	Produced and lost in mining, assuming past losses equal production		
Alabama	67,570,000	---	---	---	67,570,000	821,590	1,643,180	65,926,820	32,963,410
Arkansas	1,396,000	---	90,000	230,000	1,716,000	91,894	183,788	1,532,212	766,106
Colorado	213,071,000	104,175,000	---	100,000	317,346,000	471,146	942,292	316,403,708	158,201,854
Georgia	933,000	---	---	---	933,000	11,533	23,066	909,934	454,967
Illinois	171,905,000	---	---	---	171,905,000	3,131,997	6,263,994	165,641,006	82,820,503
Indiana	53,051,000	---	---	---	53,051,000	984,137	1,968,274	51,082,726	25,541,363
Iowa	29,160,000	---	---	---	29,160,000	343,162	686,324	28,473,676	14,236,838
Kansas	2/ 17,574,000	---	---	---	2/ 17,574,000	3/ 9,800	3/ 19,600	17,554,400	8,777,200
Kentucky	123,327,000	---	---	---	123,327,000	1,951,803	3,903,606	119,423,394	59,711,697
Maryland	8,043,000	---	---	---	8,043,000	259,943	519,886	7,523,114	3,761,557
Michigan	296,900	---	---	---	296,900	4/ 46,240	5/ 77,000	219,900	109,950
Missouri	79,362,016	---	---	---	79,362,016	257,787	515,574	78,846,442	39,423,221
Montana	2,362,610	132,151,060	87,533,270	---	222,046,940	157,248	314,496	221,732,444	110,866,222
New Mexico	10,947,700	50,801,200	---	5,700	61,754,600	121,507	243,014	61,511,586	30,755,793
North Carolina ..	110,462	---	---	---	110,462	1,054	2,108	108,354	54,177
North Dakota	---	---	600,000,000	---	600,000,000	67,856	135,712	599,864,288	299,932,144
Ohio	86,497,000	---	---	---	86,497,000	1,694,259	3,388,518	83,108,482	41,554,241
Oklahoma	54,951,000	---	---	---	54,951,000	158,846	317,692	54,633,308	27,316,654
Pennsylvania	75,093,459	---	---	22,805,000	97,898,459	12,332,962	24,665,924	73,232,535	36,616,268
South Dakota	---	---	1,020,000	---	1,020,000	921	1,842	1,018,158	509,079
Tennessee	25,665,000	---	---	---	25,665,000	324,718	649,436	25,015,564	12,507,782
Texas	8,000,000	---	23,000,000	---	31,000,000	62,047	124,094	30,875,906	15,437,953
Utah	88,184,000	5,156,000	---	---	93,340,000	198,665	397,330	92,942,670	46,471,335
Virginia	21,149,000	---	---	500,000	21,649,000	548,479	1,096,958	20,552,042	10,276,021
Washington	11,413,000	52,442,000	---	23,000	63,878,000	142,904	285,808	63,592,192	31,796,096
West Virginia ...	116,618,447	---	---	---	116,618,447	4,979,385	9,958,770	106,659,677	53,329,838
Wyoming	13,234,950	6/108,318,900	6/ ---	---	121,553,850	362,375	724,750	120,829,100	60,414,550
Other states	7/ 820,000	8/ 15,500,000	9/ 49,963	---	16,369,963	8,789	17,578	16,352,385	8,176,193
Total	1,280,735,544	468,544,160	711,693,233	23,663,700	2,484,636,637	29,543,047	59,070,614	2,425,566,023	1,212,783,012

1/ Production, 1800 through 1885, from The first century and a quarter of American coal industry, by H. N. Eavenson, privately printed, 1942; production, 1886 through 1949, from U. S. Bureau of Mines Minerals Yearbooks, unless otherwise indicated.
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4/ Michigan Geological Survey Division, as cited in U. S. Geological Survey Circular 77, p. 56, 1950.
5/ Past losses assumed to be 40 percent of coal originally in the ground.
6/ Small reserves of lignite included under subbituminous coal.
7/ Includes Arizona, California, Idaho, and Oregon.
8/ Includes Arizona, California, and Oregon.
9/ Includes California and Louisiana.

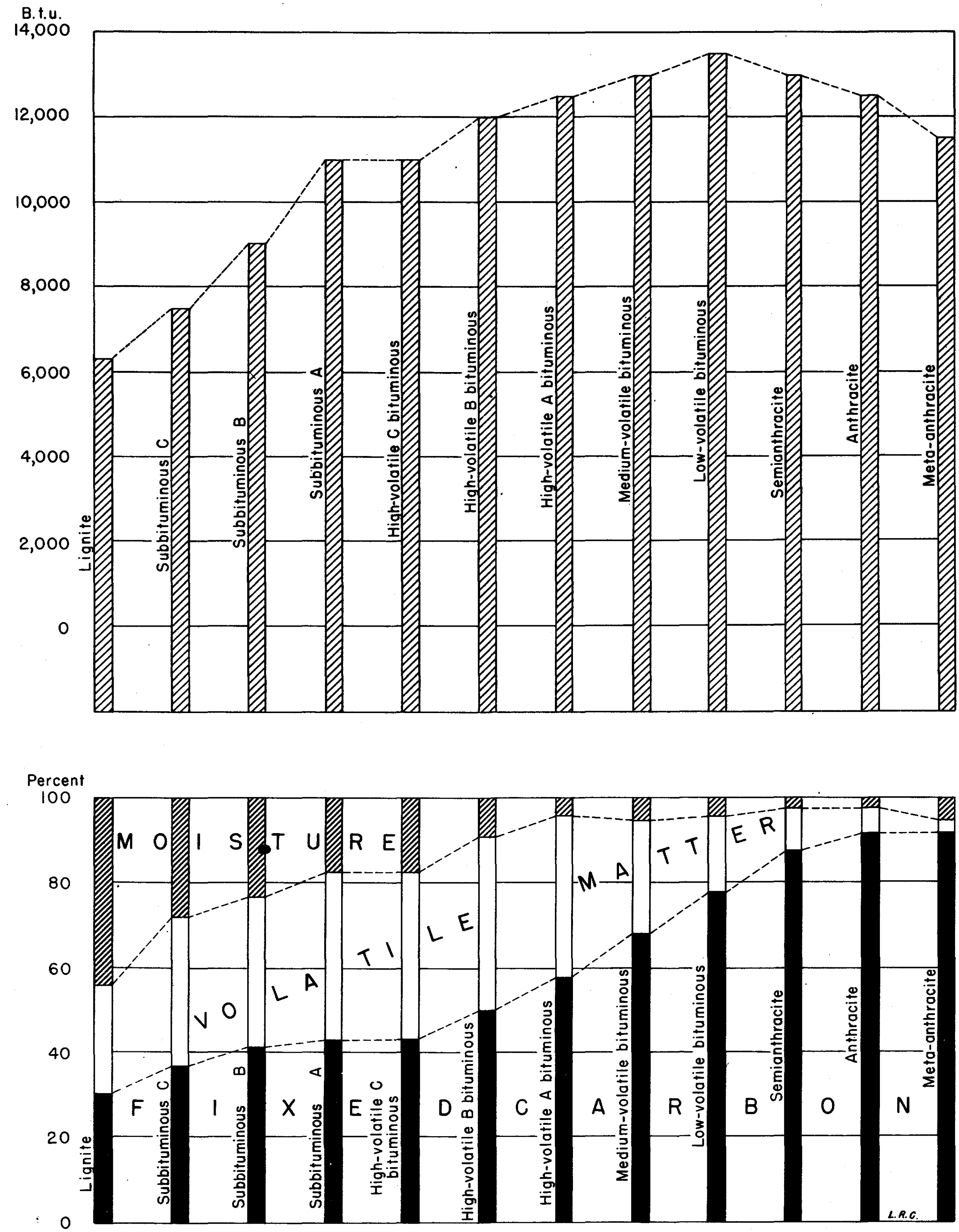

Figure 3. - Heat value of coal of different ranks compared to proximate analyses.

Upper diagram: Comparative heat value of typical samples of the several ranks of coal, computed on samples as received, on the ash-free basis. Lower diagram: Variation in the fixed carbon, volatile matter, and moisture of samples used in upper diagram, computed on samples as received, on the ash-free basis.

CLASSIFICATION OF COALS BY RANK.[a]

Legend: F.C. = Fixed Carbon. V.M. = Volatile Matter. Btu. = British thermal units.

Class	Group	Limits of Fixed Carbon or Btu. Mineral-Matter-Free Basis	Requisite Physical Properties
I. Anthracitic	1. Meta-anthracite	Dry F.C., 98 per cent or more (Dry V.M., 2 per cent or less)	
	2. Anthracite	Dry F.C., 92 per cent or more and less than 98 per cent (Dry V.M., 8 per cent or less and more than 2 per cent)	
	3. Semianthracite	Dry F.C., 86 per cent or more and less than 92 per cent (Dry V.M., 14 per cent or less and more than 8 per cent)	Nonagglomerating[b]
II. Bituminous[d]	1. Low volatile bituminous coal	Dry F.C., 78 per cent or more and less than 86 per cent (Dry V.M., 22 per cent or less and more than 14 per cent)	
	2. Medium volatile bituminous coal	Dry F.C., 69 per cent or more and less than 78 per cent (Dry V.M., 31 per cent or less and more than 22 per cent)	
	3. High volatile *A* bituminous coal	Dry F.C., less than 69 per cent (Dry V.M., more than 31 per cent); and moist[c] Btu., 14,000[e] or more	
	4. High volatile *B* bituminous coal	Moist[c] Btu., 13,000 or more and less than 14,000[e]	
	5. High volatile *C* bituminous coal	Moist Btu., 11,000 or more and less than 13,000[e]	Either agglomerating or nonweathering[f]
III. Subbituminous	1. Subbituminous *A* coal	Moist Btu., 11,000 or more and less than 13,000[e]	Both weathering and nonagglomerating
	2. Subbituminous *B* coal	Moist Btu., 9500 or more and less than 11,000[e]	
	3. Subbituminous *C* coal	Moist Btu., 8300 or more and less than 9500[e]	
IV. Lignitic	1. Lignite	Moist Btu., less than 8300	Consolidated
	2. Brown coal	Moist Btu., less than 8300	Unconsolidated

[a] This classification does not include a few coals which have unusual physical and chemical properties and which come within the limits of fixed carbon or Btu. of the high-volatile bituminous and subbituminous ranks. All of these coals either contain less than 48 per cent dry, mineral-matter-free fixed carbon or have more than 15,500 moist, mineral-matter-free Btu.

[b] If agglomerating, classify in low-volatile group of the bituminous class.

[c] Moist Btu. refers to coal containing its natural bed moisture but not including visible water on the surface of the coal.

[d] It is recognized that there may be noncaking varieties in each group of the bituminous class.

[e] Coals having 69 per cent or more fixed carbon on the dry, mineral-matter-free basis shall be classified according to fixed carbon, regardless of Btu.

[f] There are three varieties of coal in the high-volatile C bituminous coal group, namely, Variety 1, agglomerating and nonweathering; Variety 2, agglomerating and weathering; Variety 3, nonagglomerating and nonweathering.

change with new mapping and exploration, is essentially a constant, needing no date nor explanation to make it understandable. From this estimate the figures for remaining and recoverable reserves, which must be dated, can be determined annually, if desired, from available information on production and losses or from surveys of mined-out areas.

The only instance in which coal reserves can be calculated successfully without reference to original reserves is in virtually mined-out areas where remaining reserves are small and clearly defined. In most coal areas in the United States, however, the remaining reserves still closely approximate the original reserves. This is particularly true in the West, where relatively little mining has been done.

PERCENTAGE OF COAL RECOVERED IN MINING

For calculating remaining and recoverable reserves, reasonably accurate figures for the past production of coal can be obtained from statistics on annual production. The figures for past and estimated future losses of coal in mining, also needed in these calculations, are not so easily obtained. In localities covered by detailed mine maps, past losses in mining can be determined by a comparison of production figures with measurements of areas known to be mined out. The necessary detailed maps are not available, however, for many of the coal-mining areas in the United States, and the estimates of individuals familiar with local mining operations provide, in general, the only indication of the relative tonnages of coal that are recovered and lost in mining.

The percentage of the total coal recovered in mining varies to a considerable extent, depending upon such factors as the structure of the coal beds and the methods used in mining. In calculating remaining and recoverable reserves on a regional or national scale, therefore, an average figure for the estimated percentage of recovery in the past and in the future must be derived from a consideration of the relatively few detailed studies available. Most studies of recoverability involve consideration of individual mines or small areas and typically indicate a higher recoverability than studies of larger areas. In some individual mines, for example, as much as 80 or 90 percent of the coal in the block actually being mined may be recovered. From the total-resource point of view, however, recoverability appears to be only about 50 percent of the coal in the ground. This marked difference is due to the fact that studies of recoverability in larger areas include consideration of coal that is left in barrier pillars, in restricted areas around oil and gas wells, under towns, railroads, roads, and streams, in rider beds, in thin and impure beds, and in areas of faulting and folding, as well as the more conspicuous losses in the block or blocks of coal actually being mined.

The results of an investigation by Cady (1949) of the coal resources of Franklin County, Ill., for example, have shown a recovery of less than 50 percent of the coal originally present in the No. 6 bed in that county. A similar study by Flint (1949) has indicated that the recovery of coal in Perry County, Ohio, between 1838 and 1948 was only 43 percent of the amount originally present. In Michigan the recovery of coal has averaged about 60 percent of the total coal in the ground, according to the estimates of Frank Pardee, Mining Engineer, Michigan Geological Survey Division, and Louis Gabrick, Mine Inspector, Michigan Department of Labor (Cohee and others, 1950, p. 5). B. W. Dyer has stated in a personal communication that in his opinion mining operations in Utah have not been able to recover more than 50 percent of the total coal in the ground.

Eavenson (1946) has estimated that the actual recovery from the Pittsburgh bed in Pennsylvania is not more than 50 to 60 percent because of the large amount of coal that is left in the barriers, in reservations for oil and gas wells, under buildings, and in the rider above the main bed. In calculating the remaining reserves of bituminous coal in Pennsylvania, Ashley (1944) assumed a recovery of 50 percent for all coal in the State with the exception of that in the Pittsburgh bed, for which he assumed a recovery of 66 2/3 percent. Ashley's figures were based on the percentage recovery of coal in Fayette County, Pa., as determined by Moyer (Hickok and Moyer, 1940). The weighted average recovery of bituminous coal in Cambria County, Pa., was determined by Dowd and others (1950) to be 48.77 percent.

As the results of these recently completed studies seem to be in accord, the estimated remaining and recoverable reserves of coal shown in tables 1 and 2 are based on the assumption that past mining operations have recovered only 50 percent of the coal in the ground and that this rate will be maintained in the future. Many individual operations recover more than 50 percent of the coal in the ground, however, and it is to be hoped that the general introduction of more efficient mining methods will result in a higher average recoverability in the future than the 50-percent factor assumed in the preparation of tables 1 and 2.

As production statistics generally include only the output of the larger mines, the total recorded production figures used in tables 1 and 2 are somewhat less than actual production. Thus the past losses in mining, which are assumed in tables 1 and 2 to be equal to past production, are also somewhat less than actual losses. Therefore, the remaining and recoverable reserves as reported in tables 1 and 2 are somewhat higher than they would be if full and complete data were available for the amounts of coal mined and lost in mining.

PROCEDURES USED IN CALCULATING COAL RESERVES

Estimates of coal reserves, like those of other mineral resources, are based on a series of assumptions in addition to the facts available from geologic observations, mining, and drilling. No uniform method has been adopted for calculating coal reserves, and estimates of the tonnage of coal within individual areas tend to vary greatly, depending upon the assumptions and procedures used in preparing the estimates. An estimate of coal reserves has meaning, therefore, only when considered in relation to the procedure followed in obtaining it.

For practical purposes, two cut-off points are required in calculating coal reserves--one at the minimum thickness of coal included in the estimate and another at the maximum thickness of overburden allowed above the coal. To date, however, no opinion is generally accepted as to what figures represent the practical limits to be used for the thickness of coal beds and of overburden. A very conservative estimate may include only the original reserves in thick beds and under slight overburden--in other words, reserves that could be recovered profitably under current mining conditions. A more inclusive estimate, on the other hand, may consider thinner, more impure, and more deeply buried coal as recoverable by improved methods when more easily mined deposits have been exhausted.

Other standards, in addition to those involving thickness of coal beds and of overburden, are employed in calculating coal-reserve estimates. The weight or specific gravity of the coal is determined or assumed, and the method of determining the extent of coal underground at a distance from an outcrop, mine, or drill hole is selected. Again, these standards vary with individual estimates, and the tonnages of coal in the estimates vary accordingly.

The U. S. Geological Survey, in order to produce uniformity of thinking and procedure on the part of Survey coal geologists, has adopted a set of procedures to be used in the calculation of coal reserves. Estimates of coal reserves thus obtained can easily be combined in county, state, and national totals of comparable value.

These procedures, which were prepared jointly by members of the Geological Survey and the Bureau of Mines and include recommendations of the National Bituminous Coal Advisory Council, are discussed in the following paragraphs.

THICKNESS OF BEDS

In areas where coal beds are of varying thicknesses, the average thickness of each bed is determined for use in calculations of reserves. No standard procedure for determining such thickness is in use, but generally an average thickness or weighted average thickness is obtained from the observed thicknesses of the coal bed at various locations within the area. Occasionally, in older coal-reserve estimates, the "modulus of irregularity" has been used to determine the probable minimum thickness of a coal bed. According to this formula, the probable minimum thickness is obtained by multiplying the average of the measurements of the thickness of the coal bed by $(1 - \frac{SD}{S})$, in which S is the sum of all measurements and SD is the sum of the numbers obtained by subtracting from the average each measurement below it or subtracting the average from each measurement above it.

The modulus of irregularity was originally adopted by the U. S. Geological Survey as a mechanism in establishing the value of coal lands, (Smith, 1913) but it is no longer used for this purpose. As described in U. S. Geological Survey Bulletin 537, it was devised as a safeguard for the buyer of coal lands in areas where the coal beds vary in thickness within wide limits. Computation of the thickness of the coal by using the modulus of irregularity permitted the "thickness of the coal under any tract of land to be considered as less than the average of the measurements. For while the coal is as likely to be just above the average as just below, and mathematically, is more likely to be just the average thickness than any other, yet a cautious buyer bargaining for coal would always want to discount the probability a little as a matter of safety." The modulus of irregularity is cumbersome and inappropriate for use in the appraisal of coal reserves.

According to the procedures of the U. S. Geological Survey, coal reserves are calculated and reported by beds in categories of thickness as follows:

Anthracite, semianthracite, and bituminous coal
- More than 42 inches
- 28 to 42 inches
- 14 to 28 inches

Subbituminous coal and lignite
- More than 10 feet
- 5 to 10 feet
- $2\frac{1}{2}$ to 5 feet

The thickness of a coal bed is evaluated wherever possible by the use of isopach lines. Generally, however, the data are insufficient for this purpose, and average figures, which are weighted according to the approximate area of bed represented by each observation, are used. If the points of observation are not evenly spaced, the weighting is accomplished by assigning intermediate values for the thickness at places where data are needed to fill out a system of evenly spaced points. Where this procedure is followed to obtain the weighted average thickness along the outcrop of a persistent bed, the two end points of minimum thickness are also included in the average. Where the points of observation are fairly evenly spaced, as in an exploratory or development drilling program, a simple average is deemed sufficient.

Partings more than three-eighths of an inch thick are omitted in determining the thickness of individual beds. Beds and parts of beds made up of alternating layers of thin coal and partings are omitted if the partings make up more than one-half the total thickness or if the ash content exceeds 33 percent. Benches of coal of less than the minimum thicknesses stated, which lie above or below thick partings and which normally would be left in mining, are also omitted.

AREAL EXTENT OF BEDS

The areal extent of coal beds included in U. S. Geological Survey reserve estimates may be determined in several ways. Where the continuity of the bed is well known from maps of the outcrop, mine workings, and drill holes, the entire area of the known occurrence of the bed is taken, even though points of observation are widely spaced. Persistent beds that have been traced around a basin or spur are considered to underlie the area enclosed by the outcrop. Otherwise, the length of outcrop within the thickness limits listed is considered to determine the presence of coal in a semicircular area having a radius equal to one-half the length of the outcrop. The total area of coal is considered to extend beyond such a semicircle if mine workings or drill holes so indicate, in which case coal is considered to extend only 1 mile beyond the limits of the mine workings. An isolated drill hole too far removed to be incorporated in the area thus defined is considered to determine the area of coal extending for a maximum radius of half a mile around the hole.

OVERBURDEN

Wherever possible, reserve data are reported by the U. S. Geological Survey in three classes, according to thickness of overburden, as follows:

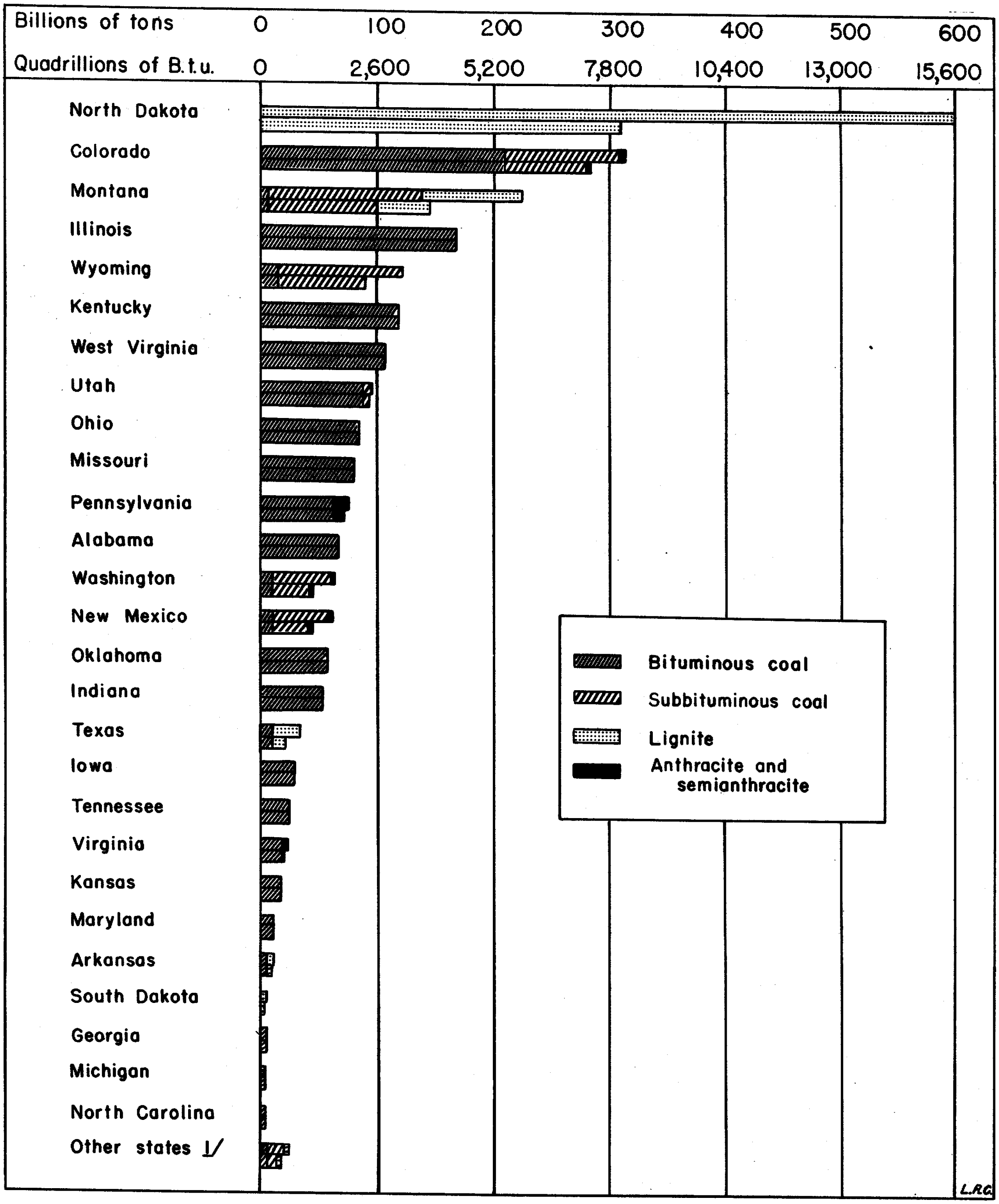

Figure 4.- Remaining coal reserves of the United States, January 1, 1950, by states according to tonnage and heat value

[Upper bar for each state shows coal reserves by tons; lower bar shows coal reserves by B.t.u.]

1/ Includes Arizona, California, Idaho, Louisana, and Oregon.

0 to 1,000 feet
1,000 to 2,000 feet
2,000 to 3,000 feet

MEASURED, INDICATED, AND INFERRED RESERVES

On the basis of the relative abundance of reliable data on which the calculations are based, coal reserves are reported by the U. S. Geological Survey in three classes, known as measured, indicated, and inferred.

Measured coal is coal for which tonnage is computed from dimensions revealed in outcrops, trenches, mine workings, and drill holes. The points of observation and measurement are so closely spaced, and the thickness and extent of the coal are so well defined that the computed tonnage is judged to be accurate within 20 percent or less of the true tonnage. Although the spacing of the points of observation necessary to demonstrate continuity of coal varies in different regions according to the character of the coal beds, the points of observation are, in general, about half a mile apart.

Indicated coal is coal for which tonnage is computed partly from specific measurements and partly from projection of visible data for a reasonable distance on geologic evidence. In general, the points of observation are approximately 1 mile apart, but they may be as much as $1\frac{1}{2}$ miles apart for beds of known geologic continuity.

Inferred coal is coal for which quantitative estimates are based largely on broad knowledge of the geologic character of the bed or region and for which there are few, if any, measurements. The estimates are based on an assumed continuity for which there is geologic evidence. In general, inferred coal lies more than 2 miles from the outcrop.

WEIGHT OF COAL

Where precise data are not available, the following values are assigned as the weight of coal in all U. S. Geological Survey calculations of coal reserves:

	Tons per acre-foot
Anthracite and semianthracite	2,000
Bituminous coal	1,800
Subbituminous coal	1,770
Lignite	1,750

DISTRIBUTION OF COAL IN THE UNITED STATES

Coal deposits are widely distributed throughout the United States, as shown in figure 1, which also shows the very unequal distribution of coal according to rank. Only 30 percent of the total coal reserves of the United States occur east of the Mississippi River, yet this area contains 60 percent of the total reserves of bituminous coal and anthracite. The coal-bearing states west of the Mississippi River contain 70 percent of the total reserves of the Nation, but most of the coal is of lignite, subbituminous, or high-volatile bituminous rank.

This variation in rank of coal according to geographic distribution is principally the result of differences in age. In the East, and in Kansas, Iowa, Oklahoma, and Arkansas, the coal is of Pennsylvanian age; in the West, on the other hand, the coal is of Cretaceous or Tertiary age. The younger Western coal attains high rank only locally, in relatively small areas, where it has been deformed and altered by the forces that accompanied mountain building and intrusions of igneous rock.

The best grades of coke are manufactured from medium-volatile bituminous coal or from blends of high-volatile and low-volatile bituminous coal. Most of the deposits of coal suitable for the manufacture of metallurgical coke, therefore, are east of the Mississippi River, in areas where mining has been carried on extensively. Some areas in the West, of which the most important are the Raton Mesa region, Colorado-New Mexico, the Sunnyside field, Utah, and the Crested Butte field, Colorado, contain deposits of coal that are used in coke production. These areas stand out prominently in plans for the industrial development of the West.

The far larger reserves of lignite and subbituminous coal in the West have only local value at present, though it seems certain that they will have greater usefulness in the future. Coal of these ranks tends to crumble during transportation and to ignite by spontaneous combustion if stored without special precautions for too long a period. It also has a lower heat value than other coal. On the other hand, the low-rank coal is well suited for the synthetic production of gas and liquid fuels, and, as this coal lies under very light overburden in many parts of the West, it is also well suited for strip-mining, which is being carried on locally in the West with great efficiency.

Most of the tables and illustrations in this report show reserves of all ranks of coal in short tons as computed. In terms of ultimate usefulness, however, comparison of the reserves of lignite and subbituminous coal, which have relatively low heat values, with reserves of bituminous coal and anthracite, which have higher heat values, can best be made on a uniform B. t. u. basis. Such a comparison is presented in figure 4, which shows the remaining reserves in each state as of January 1, 1950, on both a tonnage and a B. t. u. basis. The B. t. u. content of typical coal in each rank and subdivision is given in figure 3.

As somewhat different assumptions and procedures were used to prepare many of the state reserve estimates presented in this report, comparison of the reserves in different states is further facilitated by a consideration of the methods by which each estimate was obtained. Even in the recent appraisals of coal reserves in Michigan, Montana, New Mexico, North Carolina, and Wyoming, which were prepared by the U. S. Geological Survey according to the basic outline already discussed, minor differences in procedures were necessary because of differences in the occurrence of the coal and in the amount of information available. Even greater differences in assumptions and procedure exist between estimates prepared by the State geological surveys of Illinois, Kansas, Pennsylvania, and West Virginia. The following summaries, arranged in alphabetical order according to the name of the state, describe and evaluate the various methods followed in preparing the individual state estimates. Wherever possible, the reserve figures for each state are further classified according to thickness of coal beds, amount of overburden, and abundance of reliable information, in order to give the estimates additional significance and usefulness. States for which no recent estimates are available, and for which the older estimates of M. R. Campbell are used, are included under the heading "Other states."

Although the methods employed in preparing appraisals of reserves in a few states are markedly different from those used in the majority of states, no attempt has been made in any of the tables or illustrations used throughout this report to introduce arbitrary mathematical adjustment in the published figures. It was felt that the differences represent studied decisions by the appraisors and are due probably to differences in the occurrence of the coal, amount of information available for making an appraisal, and other local factors not susceptible to simple mathematical adjustment. The different methods employed have given results of somewhat different magnitude, however, and deserve careful consideration.

ILLINOIS

The original reserves of coal in Illinois, as estimated by Cady, (1946) totaled 171,905,000,000 tons, all of bituminous rank. Cady based his reserve figure for the most part upon a consideration of the previously published estimates of the coal reserves of various mining districts in Illinois (Cady, 1915, 1916, 1917, 1919, 1921; Culver, 1925; Kay, 1915; Kay and White, 1915), and also upon more recently acquired data about the coal beds in the State. (Cady, 1944, p. 44).

All coal beds averaging 2 feet or more in thickness were included in the estimate. In the calculation of the reserves a specific gravity of 1. 3, or a weight per acre-foot of 1,770 tons, was assumed.

Tables were prepared to show the distribution of the total coal reserves of Illinois by counties and by mining districts. As most of the coal in Illinois lies under a moderate overburden, no attempt was made to classify the reserves according to thickness of overburden, nor were attempts made to classify the reserves according to bed thickness or abundance of reliable information used in making the reserve estimate.

INDIANA

The estimated original reserves of coal in Indiana, according to Campbell, totaled 53,051,000,000 tons, all of bituminous rank. This figure is based upon detailed estimates by Ashley (1898 and 1908).

In the 1898 report Ashley estimated the original coal reserves of Indiana to be 39,618,240,000 tons but later, in 1908, increased the figure to 46,864,000,000 tons. The original publication shows the total coal reserves of Indiana classified by coal beds and by counties; the supplementary publication shows reserves by counties only. In both estimates, Ashley included all coal beds 1 foot or more in thickness and assumed a specific gravity of 1. 15, or a weight of 1,560 tons per acre-foot, for the coal. In the actual calculations of reserves, however, Ashley rounded off the figure for the weight of the coal and used a factor of 1,500.

Ashley estimated the recoverable coal reserves of Indiana as of January 1, 1908, to be 13,621,600,000 tons. In obtaining this figure, he included all beds $2\frac{1}{2}$ feet or more in thickness and assumed a recovery of 60 percent for the coal. On this basis, the recoverable reserves of the State in beds $2\frac{1}{2}$ feet or more thick are 29. 2 percent of the original reserves.

Campbell accepted Ashley's 1908 estimate for the total coal reserves of Indiana but recalculated the estimate to the selected specific gravity of 1. 3, or a weight of 1,770 tons per acre-foot, for the coal. In making the recalculation Campbell apparently compared Ashley's stated figure of 1,560 tons per acre-foot to his own preferred figure of 1,770 tons per acre-foot and thereby obtained a total of 53,051,000,000 tons.

KANSAS

The estimated potential bituminous coal reserves of Kansas remaining in the ground on January 1, 1946, totaled 17,574,000,000 tons, of which 949,323,000 tons is classified as proved reserves. The proved reserves include 60,000,000 tons of coal which can be produced by strip-mining methods under present conditions. These estimates were made in 1945 and 1946 by Abernathy, Jewett, and Schoewe (1947) on the basis of geologic data collected by the State Geological Survey of Kansas and drilling records obtained from coal-mining companies. Tables were prepared to show the distribution of proved and potential reserves by counties and by coal beds.

In calculating the proved reserves, with the exception of that part classified as strippable coal, the following table was used to indicate the minimum thickness of coal considered minable at various depths:

Maximum depth to coal (In feet)	Minimum thickness of coal (In inches)
100	16
150	18
200	22
600	32
1,200	36

The minimum thickness of coal beds included in proved strippable reserves and in potential reserves was 10 inches. Strippable coal considered in the reserve estimate had a maximum depth of 60 feet or an overburden of not more than 35 cubic yards per ton of coal. The maximum overburden used in determining proved coal reserves was 1,200 feet, and the maximum overburden for potential reserves was 3,000 feet, the maximum generally used in estimating coal reserves in the United States.

The proved reserves of coal, as defined in the report of the State Geological Survey of Kansas, were those lying within a reasonable distance from a known occurrence of coal, based on the experience of the coal industry and on geological observations of the continuity of coal beds in Kansas. The limits of potential reserves, on the other hand, were based on the general regional stratigraphic continuity of the coal-bearing rocks. In calculating the area underlain by proved reserves, a measured thickness of coal at an outcrop, at a drill hole, or in a mine was considered to prove the presence of coal of the same thickness under 1 square mile. Two or more known occurrences of the same coal bed within a distance of 4 miles along the line of strike were considered to prove the bed to be continuous between these points. In calculating the potential reserves, a measured thickness of coal at an outcrop, at a drill hole, or in a mine indicated the presence of coal of the same thickness under 400 square miles. The areas of both classes of coal reserves were greatly reduced in many places because of additional information about the location of poor coal, thin coal, or the absence of coal.

In computing the tonnages of coal in the Kansas report, a specific gravity of 1. 1, or a weight per acre-foot of 1,500 tons, was assumed. This is a very low specific gravity for average bituminous coal in the ground, which more generally is assumed to have a specific gravity of 1. 32, or a weight of 1,800 tons per acre-foot. Had the average weight of the coal in Kansas been assumed to be 1,800 tons per acre-foot, the estimate of reserves remaining in the ground on January 1, 1946, would have been increased 20 per cent, to 1,139,187,600 tons for the proved reserves and 21,088,800,000 tons for potential reserves. The more conservative figures, based on a weight of 1,500 tons per acre-foot, are preferred by the members of the Kansas Geological Survey, however, and these figures are used in tables 1 and 2.

MARYLAND

The original reserves of coal in Maryland, all of bituminous rank, totaled 8,043,000,000 tons as estimated by Campbell in 1928. The coal-bearing rocks occur in three parallel structural troughs that extend northeastward across Garrett and Allegany Counties in the western part of the State. Within these three troughs, five separate coal fields, or coal basins, are recognized. The easternmost trough is divided by the Potomac and Savage Rivers into the Georges Creek basin to the north and the Upper Potomac basin to the south. The central trough is divided into the Castleman basin to the north and the Upper Youghiogheny basin to the south. The westernmost trough is known as the Lower Youghiogheny basin. According to Campbell, the original reserves of coal in each of these basins were as follows:

Campbell included in his estimate coal 14 inches or more thick lying under as much as 3,000 feet of overburden. He assumed a specific gravity for the coal of 1. 3 or a weight of 1,770 tons per acre-foot. In estimating the coal reserves of Maryland, Campbell had only a small amount of data available on the thickness and continuity of the beds, and, in the light of more recent mapping and exploratory drilling, his estimate now appears to be considerably larger than the actual amount of coal in the State that can be mined under present economic conditions. Campbell's estimate serves, however, to show the approximate relative distribution of reserves in the five basins.

In 1949, the results of a cooperative program of drilling and geologic investigations by the U. S. Bureau of Mines and the U. S. Geological Survey in the Georges Creek basin and the northern part of the Upper Potomac basin in Maryland were published by the Bureau of Mines. (Toenges and others, 1949) This study showed that on January 1, 1947, remaining measured and indicated reserves of 399,214,000 tons were present in beds 18 inches or more thick lying below the Pittsburgh bed. Of this total, 56,118,000 tons was in beds 18 to 24 inches thick, 220,059,000 tons in beds 24 to 36 inches thick, and 123,037,000 tons in beds more than 36 inches thick. Because of the depth at which much of the coal occurs in the Georges Creek and Upper Potomac basins, however, few of the beds under 36 inches thick can be mined profitably.

The Georges Creek basin and the northern part of the Upper Potomac basin covered by the cooperative study include approximately 60 percent of the coal reserves in Maryland according to Campbell's figures on the relative distribution of reserves in the five basins. On this basis, the total remaining measured and indicated reserves of the State as of January 1, 1947, in beds 18 inches or more thick were about 665 million tons.

Original coal reserves of Maryland by basins as estimated by M. R. Campbell

	Original reserves (In short tons)	Percent of total
Georges Creek basin	4,373,000,000	50
Upper Potomac basin.........	1,664,000,000	20
Castleman basin	229,000,000	5
Upper Youghiogheny basin	1,035,000,000	15
Lower Youghiogheny basin	742,000,000	10
Total	8,043,000,000	100

MICHIGAN

As estimated by Cohee and others (1950) the original coal reserves of Michigan totaled 296,900,000 tons. This figure includes remaining reserves as of January 1, 1950, totaling 219,900,000 tons plus an estimate for coal mined and lost in mining to January 1, 1950, totaling 77,000,000 tons. The reserves remaining on January 1, 1950, include 124,870,000 tons of measured reserves, 28,980,000 tons of indicated reserves, and 66,050,000 tons of inferred reserves. The estimate of 77,000,000 tons for coal mined and lost in mining to January 1, 1950, includes the recorded production of 46,239,607 tons, plus an allowance for coal lost in mining estimated by Pardee and Gabrick (see page 8.) to be equal to about 40 percent of the coal originally in the ground. To prepare the estimate, which is classified to show the distribution of total reserves by counties and by townships, data were assembled from published and unpublished reports in the files of the Michigan Geological Survey Division, and more than 2,500 logs of coal test wells and several hundred sets of drill cuttings from exploratory wells for oil and gas were examined.

As coal in Michigan occurs sporadically in isolated beds that vary greatly in thickness and generally pinch out in relatively short distances, satisfactory estimates of extent and average thickness were possible only for relatively small areas. In preparing the estimate of Michigan coal reserves, therefore, only those areas having adequate test-hole information were considered, and no estimate was attempted for a large part of the Michigan coal basin where coal should be present but where specific information was lacking. The part of the coal basin for which the necessary information was available was confined to the Saginaw Valley, south and southeast of Saginaw Bay, and included 33 townships in Bay, Tuscola, Midland, Saginaw, Huron, Shiawassee, and Genesee Counties.

The measured coal reserves in Michigan were divided into the following categories according to the thickness of the coal beds:

More than 42 inches
28 to 42 inches
14 to 28 inches

The measured reserves were also divided into the following categories according to the thickness of overburden:

50 to 100 feet
100 to 200 feet
200 to 300 feet
300 to 400 feet

No attempt was made to break down the indicated and inferred reserves into thickness and depth categories because of the small amount of information available on these reserves. The indicated and inferred reserves are contained in beds 14 inches or more thick, however, and are less than 400 feet below the surface.

In classifying the reserves according to the relative abundance and reliability of the information on which the estimate was based, the usual U. S. Geological Survey standards were modified slightly to accord with the geologic nature of the coal beds in Michigan. Measured coal was defined as coal blocked out by closely spaced drilling, and the outer limit of a block of measured coal was drawn within a few hundred feet of the outermost points of positive information. This conservative assumption was necessary to define measured coal in Michigan because of the known lack of continuity of the beds. Indicated coal was defined as coal for which tonnage estimates were based primarily on thickness measurements in isolated drill holes. It was assumed that the thickness of coal observed in the drill holes was representative of the area covered by a circle having a radius of one-eighth mile with the drill hole as its center. Inferred coal was defined as coal for which tonnage estimates were based on the isolated drill holes that were also used in computing indicated reserves. The general rule was to limit inferred coal to the area lying outside the one-eighth mile circle containing indicated reserves, and inside a circle with a radius of one-fourth mile. In some areas, however, where drill holes were more than half a mile but less than 1 mile apart, and where the evidence indicated that the coal was fairly persistent, some reserves were inferred to be present between the holes. In calculating the reserve figures, the coal in Michigan was assumed to have a specific gravity of 1.32, or a weight of 1,800 tons per acre-foot.

The accompanying table shows the estimated remaining coal reserves of Michigan as of January 1, 1950, classified according to thickness of bed, thickness of overburden, and abundance of reliable information.

Estimated remaining coal reserves of Michigan, January 1, 1950
(In thousands of short tons)

Overburden	Thickness of bed	Measured reserves	Indicated reserves	Inferred reserves	Total
		Bituminous coal			
50 to 100 ft.	(14 to 28 in.	1,180	---	---	---
	(28 to 42 in.	1/ 2,630	---	---	---
	(42 in. +	------	---	---	---
	Total	1/ 3,810	---	---	---
100 to 200 ft.	(14 to 28 in.	23,800	---	---	---
	(28 to 42 in.	64,100	---	---	---
	(42 in. +	10,160	---	---	---
	Total	98,060	---	---	---
200 to 300 ft.	(14 to 28 in.	3,920	---	---	---
	(28 to 42 in.	2/ 14,430	---	---	---
	(42 in. +	4,650	---	---	---
	Total	2/ 23,000	---	---	---
Total		124,870	3/ 28,980	3/ 66,050	219,900

1/ Includes 30 with overburden varying from 22 to 26 feet.
2/ Includes 3,010 with overburden ranging from 300 to 366 feet.
3/ Estimate not classified by thickness of bed or amount of overburden.

MISSOURI

The original coal reserves of Missouri as estimated by Hinds (1913) totaled 79,362,016,000 tons, all of bituminous rank. In Hinds' report the reserves are classified by counties, and, for certain counties, additional tables are presented to show reserves by coal beds or by townships.

Hinds included in his estimate all coal beds 14 inches or more in thickness and assumed a specific gravity of 1.32, or a weight of 1,800 tons per acre-foot, for the coal. No attempt was made to classify reserves according to thickness of bed or overburden.

Hinds further estimated that the recoverable coal reserves of Missouri, assuming ideal market and labor conditions, will not equal more than 60 percent of the original reserves, or 47,702,108,400 tons.

MONTANA

The original coal reserves of Montana totaled 222,046,940,000 tons, as estimated by Combo and others (1949). This estimate includes 2,362,610,000 tons of bituminous coal, 132,151,060,000 tons of subbituminous coal, and 87,533,270,000 tons of lignite. The distribution of the coal reserves of various ranks in Montana is also shown on a map by Combo and others (1950).

Published and unpublished detailed geologic reports in the files of the U. S. Geological Survey, publications of the Montana State Bureau of Mines and Geology, and similar sources were analyzed for data necessary for the calculation of the reserve figures. Tables were prepared to show the classification of reserves by counties. Approximately 10 percent of the total area of coal-bearing rocks in Montana was not included in the estimate because no information was available on the thickness and extent of the beds. The omitted areas are concentrated, in general, in the northeastern, lignite-bearing part of the State, where the coal-bearing rocks are concealed by glacial drift. The estimated reserves of lignite should be increased in the future as more detailed work is carried on in these areas.

The minimum thickness of coal considered in the estimate was 14 inches for bituminous coal, and 2½ feet for subbituminous coal and lignite. For the purpose of classifying the reserves, separate estimates were prepared for coal in the following thickness ranges:

Bituminous coal

More than 36 inches
24 to 36 inches
14 to 24 inches

Subbituminous coal and lignite

More than 10 feet
5 to 10 feet
2½ to 5 feet

The maximum overburden for coal included in the estimate was 2,000 feet, but as about 75 percent of the total coal was less than 1,000 feet below the surface, no classification of the reserves was made on the basis of thickness of overburden.

The assumed areal extent of each coal bed was

Estimated original coal reserves of Montana
(In thousands of short tons)

Overburden	Thickness of bed	Measured and indicated reserves	Inferred reserves	Unclassified reserves	Total
Bituminous coal					
0 to 2,000 ft.	(14 to 24 in.	278,780	167,080	---	445,860
	(24 to 36 in.	347,690	143,740	---	491,430
	(36 in.+	1,036,330	388,990	---	1,425,320
	Total	1,662,800	699,810	---	2,362,610
Subbituminous coal					
0 to 2,000 ft.	(2½ to 5 ft.	5,392,110	2,326,150	---	7,718,260
	(5 to 10 ft.	15,485,620	9,245,940	---	24,731,560
	(10 ft.+	26,370,190	15,974,920	---	42,345,110
	(Unclassified	---	---	57,356,130	57,356,130
	Total	47,247,920	27,547,010	57,356,130	132,151,060
Lignite					
0 to 2,000 ft.	(2½ to 5 ft.	4,876,170	10,177,750	---	15,053,920
	(5 to 10 ft.	6,613,070	13,135,880	---	19,748,950
	(10 ft.+	2,566,030	435,000	---	3,001,030
	(Unclassified	---	---	49,729,370	49,729,370
	Total	14,055,270	23,748,630	49,729,370	87,533,270
Total, all ranks		62,965,990	51,995,450	107,085,500	222,046,940

determined according to the standard U. S. Geological Survey methods. Coal in the narrow weathered zone at the outcrop was included in the assumed areas of coal occurrence, as was also coal under roads, railroads, and the like. All known areas of burned coal, however, were excluded.

Two classes of coal based on the quantity of reliable information available for making reserve estimates were established, as follows: Measured and indicated reserves include coal for which positive information about thickness and extent was available from surveys of the outcrop, mine workings, and drill records. The extent of such coal underground was limited everywhere, however, by a line drawn 2 miles from the outcrop, so that all coal classed as measured and indicated was less than 2 miles from the outcrop and more than 50 percent was less than 1 mile from the outcrop. Inferred reserves include, in general, coal lying more than 2 miles from the outcrop.

On the basis of about 20 specific-gravity determinations of coal from various parts of Montana, a specific gravity of 1.3, or a weight of 1,770 tons per acre-foot, was selected as being representative of lignite and subbituminous coal. A specific gravity of 1.32, or a weight of 1,800 tons per acre-foot, was selected as being representative of all the bituminous coal except that in the Red Lodge field, Carbon County, which was assigned a specific gravity of 1.39, or a weight of 1,890 tons per acre-foot.

The accompanying table shows the estimated original coal reserves of Montana classified according to rank, thickness of bed, and abundance of reliable information.

NEW MEXICO

The original coal reserves of New Mexico totaled 61,754,600,000 tons, as estimated by Read and others (1950). This figure includes 50,801,200,000 tons of subbituminous coal, 10,947,700,000 tons of bituminous coal, and 5,700,000 tons of anthracite. The estimate of the total coal reserves of New Mexico, which is classified to show reserves by counties and coal fields, was based on published and unpublished geologic and mining data concerning the coal fields. Drilling data were used where available, but exploratory drilling for coal has been carried on only in a few areas in the State.

The minimum thickness of coal considered in the estimate was 2½ feet for subbituminous coal and 14 inches for bituminous coal and anthracite. Reserve figures for the different ranks of coal were classified by thickness of bed as follows:

Subbituminous coal

More than 10 feet
5 to 10 feet
2½ to 5 feet

Estimated original coal reserves of New Mexico
(In thousands of short tons)

Overburden	Thickness of bed	Measured reserves	Indicated reserves	Inferred reserves	Reserves inferred by zones	Total
		Bituminous coal				
0 to 1,000 ft.	(14 in.+	---	----	---	2,377,900	2,377,900
	(14 to 28 in.	72,800	359,100	334,300	---	766,200
	(28 to 42 in.	151,900	334,200	27,100	---	513,200
	(42 in.+	429,500	611,600	360,100	---	1,401,200
	Total	654,200	1,304,900	721,500	2,377,900	5,058,500
1,000 to 2,000 ft.	(14 in.+	---	---	---	1,763,600	1,763,600
	(14 to 28 in.	400	7,100	694,300	---	701,800
	(28 to 42 in.	---	39,400	355,400	---	394,800
	(42 in.+	---	69,400	715,300	---	784,700
	Total	400	115,900	1,765,000	1,763,600	3,644,900
2,000 to 3,000 ft.	(14 in.+	---	---	---	1,838,900	1,838,900
	(14 to 28 in.	---	2,600	25,300	---	27,900
	(28 to 42 in.	---	600	---	---	600
	(42 in.+	---	---	376,900	---	376,900
	Total	---	3,200	402,200	1,838,900	2,244,300
Total		654,600	1,424,000	2,888,700	5,980,400	10,947,700
		Subbituminous coal				
0 to 1,000 ft.	$(2\frac{1}{2}$ ft.+	---	---	---	16,363,500	16,363,500
	$(2\frac{1}{2}$ to 5 ft.	446,800	1,021,300	1,227,000	---	2,695,100
	(5 to 10 ft.	228,100	348,400	997,600	---	1,574,100
	(10 ft.+	151,600	160,900	---	---	312,500
	Total	826,500	1,530,600	2,224,600	16,363,500	20,945,200
1,000 to 2,000 ft.	$(2\frac{1}{2}$ ft.+	---	---	---	13,154,700	13,154,700
	$(2\frac{1}{2}$ to 5 ft.	---	60,900	165,300	---	226,200
	(5 to 10 ft.	---	39,100	743,800	---	782,900
	(10 ft.+	---	121,300	537,800	---	659,100
	Total	---	221,300	1,446,900	13,154,700	14,822,900
2,000 to 3,000 ft.	$(2\frac{1}{2}$ ft.+	---	---	---	13,288,000	13,288,000
	$(2\frac{1}{2}$ to 5 ft.	---	3,600	502,000	---	505,600
	(5 to 10 ft.	---	12,100	448,600	---	460,700
	(10 ft.+	---	---	778,800	---	778,800
	Total	---	15,700	1,729,400	13,288,000	15,033,100
Total.............		826,500	1,767,600	5,400,900	42,806,200	50,801,200
		Anthracite				
0 to 1,000 ft.	(14 in.+	---	---	---	---	---
	(14 to 28 in.	900	2,500	---	---	3,400
	(28 to 42 in.	1,400	300	---	---	1,700
	(42 in.+	500	100	---	---	600
	Total	2,800	2,900	---	---	5,700
Total.............		2,800	2,900	---	---	5,700
Total, all ranks		1,483,900	3,194,500	8,289,600	48,786,600	61,754,600

Bituminous coal and anthracite
More than 42 inches
28 to 42 inches
14 to 28 inches

In areas where information about thickness of coal beds was reasonably adequate because of drilling and mining development, isopach lines were drawn on the coal beds and were used to determine variations in thickness and to establish boundaries between coal in the several thickness categories. In many districts, however, where the data were restricted to outcrop measurements, it was possible only to determine approximate thicknesses at critical points by interpolation.

Coal lying more than 3,000 feet below the surface was not included in the estimate. For coal less than 3,000 feet in depth the following categories of reserves were established according to thickness of overburden:

0 to 1,000 feet
1,000 to 2,000 feet
2,000 to 3,000 feet

The coal reserves of New Mexico were further classified according to the relative abundance and reliability of the information on which calculations were based. The categories of measured, indicated, and inferred reserves were established according to the U. S. Geological Survey standards already described. One further category was added, however, to provide for reserves which, because of the geologic nature of the coal beds and the topography and structure of the larger coal-bearing areas, would not fit into any of the three categories generally used. In New Mexico the coal beds commonly occur in zones as a series of lenticular deposits interbedded with other sedimentary rocks. Although single coal beds in New Mexico are limited in extent, the coal-bearing zones are very persistent and may be regional in occurrence. In consequence, the usual analysis of reserves by beds would not indicate the total reserves of the interior parts of the San Juan Basin or the Raton Mesa field. The coal zones were therefore subjected to further examination as zones instead of individual beds, and the additional reserves thus derived were included in a category termed "Inferred by zone."

The methods used for coal-zone calculations were similar to those used for coal beds, and the same minimum thicknesses for coal of different ranks and the same ranges in overburden thickness were established.

In calculating the reserves of New Mexico, the bituminous coal was assumed to have a specific gravity of 1.32, or a weight of 1,800 tons per acre-foot; the subbituminous coal was assumed to have a specific gravity of 1.3, or a weight of 1,770 tons per acre-foot; and the anthracite was assumed to have a specific gravity of 1.47, or a weight of 2,000 tons per acre-foot.

The estimated original reserves of New Mexico, classified according to rank of coal, thickness of bed, amount of overburden, and abundance of reliable information, are shown in the accompanying table.

NORTH CAROLINA

All the coal of commercial quality in North Carolina is contained in the Deep River field in Chatham, Lee, and Moore Counties. The original reserves of this field, as estimated by Reinemund (1949) totaled 110,462,000 tons. The reserve estimate includes only coal in the main bench of the Cumnock coal bed and in the Gulf coal bed; it does not include coal in the lower benches of the Cumnock bed, which, in general, are too high in ash, too thin, and too far below the main bed for profitable mining. In addition to bituminous coal, the estimate includes small amounts of semianthracite and anthracite where the coal has been altered locally by igneous intrusions.

The reserves were divided into three classes according to the thickness of the coal, and separate estimates were prepared for reserves in beds 14 to 24 inches thick, beds 24 to 36 inches thick, and beds more than 36 inches thick.

The reserves were also classified on the basis of overburden, and separate estimates were made for coal less than 2,000 feet in depth and for coal lying between 2,000 and 3,000 feet in depth. No coal more than 3,000 feet below the surface was included in the estimate.

A further classification of the reserve figures was made according to the relative abundance of reliable information regarding the continuity and thickness of the coal beds. Reserves were classed as measured where the tonnages were computed from thicknesses shown in closely spaced drill holes, mine workings, and outcrops; as indicated where the tonnages were computed partly from specific measurements and partly from projections of visible data; and as inferred where computations were based entirely on geologic evidence without benefit of actual measurements.

In calculating the reserves of the Deep River field, a specific gravity of 1.32, or a weight of 1,800 tons per acre-foot, was used for all coal except that metamorphosed by contact with the intrusive igneous rocks. A specific gravity of 1.47, or a weight of 2,000 tons per acre-foot, was assumed for this metamorphosed coal.

The accompanying table shows the estimated original coal reserves of North Carolina classified according to thickness of bed, amount of overburden, and relative abundance of reliable information.

Estimated original coal reserves of North Carolina
(In thousands of short tons)

Overburden	Thickness of bed	Measured reserves	Indicated reserves	Inferred reserves	Total
		Bituminous coal			
0 to 2,000 ft.	(14 to 24 in.	8,423	18,612	23,561	50,596
	(24 to 36 in.	8,027	17,943	---	25,970
	(36 in.+	15,635	3,851	—	19,486
	Total	32,085	40,406	23,561	96,052
2,000 to 3,000 ft.	(14 to 24 in.	---	---	---	---
	(24 to 36 in.	1,063	13,347	---	14,410
	(36 in.+	---	---	---	---
	Total	1,063	13,347	---	14,410
Total		33,148	53,753	23,561	110,462

OHIO

According to combined estimates of Clark (1929) and Flint (1949), the original coal reserves of Ohio totaled 86,497,000,000 tons, all of bituminous rank. In 1929 Clark estimated the original reserves of Ohio to be 87,638,000,000 tons, of which 2,141,000,000 tons was estimated to be in Perry County. On the basis of new geologic work in 1949 Flint recalculated the reserves of Perry County and estimated the original reserves to be only 1,000,000,000 tons. This new figure has been added to Clark's estimate for the remainder of the State to give the present total reserve estimate.

Clark based his estimate, which includes a table showing reserves by counties and by coal beds, upon data assembled for the most part from reports of the Geological Survey of Ohio. All coal in beds 14 inches or more thick to a depth of 3,000 feet below the surface was included in the estimate. Average thicknesses for each bed by counties were obtained.

The areal extent of the coal underground was determined by various methods depending upon the amount of information available to Clark on each coal bed. Higher beds, whose outcrops encircle upland areas, were assumed to underlie the area enclosed by the outcrop. Except where positive evidence indicated the absence of coal, each of the lower beds was assumed to extend below drainage toward the center of the coal basin at right angles to the strike for a distance equal to the distance that the bed was known to extend above drainage. Where the coal bed was believed to be persistent along its outcrop and reasonably constant in thickness, it was assumed to have the same average thickness below drainage as observed above drainage.

Several of the coal beds in Ohio were not shown on the maps available to Clark. The probable area of these beds had to be determined from maps showing the outcrop of the base of the coal measures, the outcrops of the more important coal beds, and the locations of coal sections; from the records of deep borings; and from references in the texts of the State reports.

In the calculation of the reserves a specific gravity of 1.32, or a weight of 1,800 tons per acre-foot, was assumed for the coal.

In the more recent work in Perry County, Flint also used 14 inches as the minimum thickness of coal included in his estimate. Of the seven coal beds that Clark recognized in Perry County, however, four beds were excluded by Flint from his estimate, because detailed mapping showed that in this county these beds generally are less than a foot thick or are completely missing. In calculating the reserves, Flint assumed the coal to have a specific gravity of 1.32, or a weight of 1,800 tons per acre-foot.

Of the total 1,000,000,000 tons of coal estimated to have been originally present in Perry County, 208,000,000 tons have been mined out or lost in mining. The remaining reserves as of January 1, 1949, therefore total 792,000,000 tons.

Flint conducted a study of the recovery of coal in mining operations in Perry County from 1838 to 1948 which showed that during this period only 43 percent of the coal was recovered. This figure was based upon measurements of mined-out areas in the county as compared to production statistics. On this basis, the recoverable reserves of coal in Perry County total 340,000,000 tons.

According to an estimate by Ray (1929, p. 330), approximately one-sixth of the total original reserves of coal in Ohio, or 14,399,296,000 tons, can be classified as reserves of thick, reasonably accessible coal. For his estimate Ray included only coal 2.7 feet or more thick in 10 specified beds, and he used an assumed specific gravity of 1.1, or a weight of 1,500 tons per acre-foot, for the coal. This weight is very low for bituminous coal in the ground, however, and a more accurate, though conservative, figure can be obtained by a recalculation of Ray's estimate using a specific gravity of 1.32, or a weight of 1,800 tons per acre-foot. The estimated original reserves of thick coal in Ohio would thereby be increased 20 percent, to a total of 17,279,155,800 tons.

PENNSYLVANIA

The original bituminous coal reserves of

Pennsylvania, as estimated by Reese and Sisler (1928), totaled 75,093,459,000 tons. This figure was determined by plotting on county base maps all the information about the area and thickness of the coal beds in the State that could be obtained from the reports of the U. S. Geological Survey and the Pennsylvania Geologic and Topographic Survey, and from drill records, mine maps, and personal interviews with mine operators and others familiar with the coal fields of Pennsylvania.

All coal beds having a minimum thickness of 18 inches were included in the estimate.

An assumed specific gravity of 1.24, or a weight of 1,688 tons per acre-foot, was used in calculating the coal reserves of all the counties in Pennsylvania with the exception of Clarion and Jefferson. A specific gravity of 1.34, or a weight of 1,820 tons per acre-foot, was used in computing the coal reserves of these two counties. The specific gravity of 1.34 not only represents the average weight of the coal in two counties in Pennsylvania as determined by a large number of tests, but it also closely approximates the specific gravity of samples of typical bituminous coal in the ground. The assumed specific gravity of 1.24 used in calculating the coal reserves of most of the counties is low for typical bituminous coal, and therefore, yields a very conservative figure for the coal reserves of Pennsylvania. Had a specific gravity of 1.34 been used in the calculations for all the counties, the estimated bituminous coal reserves of Pennsylvania would have been increased by 6 percent to a total of 80,545,165,000 tons.

Several additional estimates of the coal reserves of small areas in Pennsylvania have been calculated and can be used as a partial check on the Reese and Sisler estimate for the entire State. These estimates are discussed in the following paragraphs.

The coal reserves of two adjoining quadrangles, Punxsutawney and Curwensville, were estimated by G. H. Ashley (1926 and 1940). As Reese and Sisler used counties, townships, and coal beds as a basis for their estimate, Ashley's complete estimate for two quadrangles cannot be compared with the estimate by Reese and Sisler. It is possible, however, to compare the two estimates of coal reserves for those townships which lie entirely within the Punxsutawney and Curwensville quadrangles. For the 14 townships thus situated, Reese and Sisler estimated that the original coal reserves totaled 2,347,600,000 tons, whereas Ashley estimated that the original coal reserves totaled 2,765,375,000 tons. Ashley's estimate, therefore, represents an increase of nearly 18 percent over the estimate of Reese and Sisler.

In calculating the reserves of the Curwensville quadrangle, Ashley included only coal having an average net thickness of at least 18 inches. In calculating the reserves of the Punxsutawney quadrangle, he included only coal having an average net thickness of at least 1 foot. Ashley defined the net thickness of coal bed as "the thickness left after rejecting any minor benches separated from the main bench by a parting of greater thickness than the coal bench. In the case of a parting thinner than the coal bench, only the difference in thickness between the minor bench and the parting was added to the thickness of the major bench." For both quadrangles, Ashley assumed a specific gravity of 1.32, or a weight of 1,800 tons per acre-foot, for the coal.

The coal reserves of the Smicksburg quadrangle were estimated by M. N. Shaffner (1946), but again a comparison with the Reese and Sisler estimate can be made only for the townships lying completely within the quadrangle. For six townships, therefore, Shaffner estimated that the original coal reserves totaled 525,771,000 tons, and Reese and Sisler estimated that the original reserves totaled 931,300,000 tons. Shaffner's estimate is only 56 percent of that made by Reese and Sisler.

Much of the difference between the two estimates is probably accounted for, however, by the fact that Shaffner determined the thickness of the coal beds used in his calculations by the modulus of irregularity. As already discussed, this formula results in a figure for the thickness of the coal that is less than the average thickness, and an estimate based on the use of the formula tends to be extremely conservative. This is the only known published use of the modulus of irregularity in recent calculations of coal reserves.

Shaffner assumed a specific gravity of 1.35, or a weight of 1,840 tons per acre-foot, for the coal in the Smicksburg quadrangle.

F. T. Moyer estimated that the original coal reserves of Fayette County, Pa., totaled 7,570,000,000 tons (Hickok and Moyer, 1940). For the same area Reese and Sisler estimated that the original coal reserves totaled 5,230,000,000 tons. Moyer's estimate represents an increase of 45 percent over the estimate of Reese and Sisler.

The townships in Fayette County were divided by Moyer into areas in which the coal showed the same characteristics and for which an average section could be determined. The area underlain by coal was obtained by planimeter measurements. Minable thicknesses of the average sections were used in all calculations. The minable thickness of a coal bed, as defined by Moyer, was the thickness of the coal after subtracting partings, bone, and bony coal from the total thickness of the bed. Thin benches separated by a thick parting from the principal bench of a coal bed were also excluded in considering minable thickness. No coal having an average minable thickness of less than 26 inches was included in the estimate. Moyer assumed a specific gravity of 1.37, or a weight of 1,860 tons per acre-foot, for the coal in Fayette County.

The original coal reserves in seven beds in Cambria County, Pa., were estimated by Dowd and others (1950) to total 2,406,687,000 tons. This figure represents the measured and indicated coal in beds at least 14 inches thick. Because the estimate does not include inferred reserves, it cannot be compared in its original form to the estimate of Reese and Sisler.

All calculations for the Dowd estimate were based upon an assumed specific gravity of 1.32, or a weight of 1,800 tons per acre-foot.

In the strictest sense none of the reserves figures just discussed can be compared with the Reese and Sisler estimate because of the different standards applied, particularly for minimum thickness of coal beds and weight of coal. For practical purposes, however, the several recent estimates serve to show the conservative quality of the older Reese and Sisler estimate.

Ashley (1944) recognized the conservative nature of the Reese and Sisler estimate and, on the basis of the other estimates just described, added 10 percent to the Reese and Sisler coal reserve figures for every county in Pennsylvania except Fayette County, for which he used the new estimate by Moyer.

As has already been mentioned, the low estimate by Reese and Sisler is partly the result of the use of a lower-than-average specific gravity for the coal in Pennsylvania. Recalculation of the estimate using a somewhat higher specific gravity for the coal, however, still results in a smaller figure for the coal reserves of Pennsylvania than is indicated by the other estimates included in this discussion. Considering the conservative nature of the Reese and Sisler estimate and the fact that no new complete estimate for the coal reserves of Pennsylvania is available, the continued use of their estimate without revision in the present tables seems justified at this time.

The original reserves of anthracite in Pennsylvania totaled 22,805,000,000 short tons, according to the most recent estimate, which was made by Ashley (1945). This estimate was based directly upon a previous one by Ashmead (1926), with the exception of the reserve figures for two counties, Dauphin and Lebanon, which Ashley reduced on the basis of later mining reports.

Ashmead based his reserve estimate on careful measurements of coal bed areas as shown on mine maps, but he listed no standards for the thickness or weight of the coal included. Presumably, therefore, in computing the anthracite reserves of Pennsylvania, Ashmead, and subsequently Ashley, used the same limits of thickness and the same figures for specific gravity that were adopted by Smith (1893; see also Lesley and others, 1895), who made the first careful estimate of the anthracite reserves.

The minimum thickness of coal included in Smith's estimate was 2.5 feet for the Northern anthracite field and 2 feet for the other fields.

In calculating his figure for the anthracite reserves, Smith used different values for the specific gravity of the coal in different localities within the anthracite fields, as determined by numerous tests. The coal in the Eastern Middle field, Western Middle field, and part of the Southern field was assigned a specific gravity of 1.61, or a weight of 2,190 tons per acre-foot. The remainder of the coal in the Southern field was assigned a specific gravity of 1.5, or a weight of 2,040 tons per acre-foot, and the coal in the Northern field was assigned a specific gravity of 1.55, or a weight of 2,110 tons per acre-foot. Smith estimated that the original reserves of anthracite in Pennsylvania totaled 21,848,800,000 short tons.

The several estimates of Pennsylvania anthracite reserves all were based upon assumed accordion folds in the coal-bearing rocks of the anthracite fields.

On the basis of recent work by Rothrock (1950), however, it now appears that some of these structures may be more correctly interpreted as thrust faults, in which case the reserves of anthracite may be reduced in future estimates. Smith's original estimate of 21,848,800,000 short tons may therefore prove to be more accurate than the later estimates which have tended to increase the reserve figures.

WEST VIRGINIA

The original coal reserves of West Virginia totaled 116,618,446,894 tons, according to an estimate by Headlee and Nolting (1940). This figure represents the sum of the original coal reserves of each county as estimated in county reports published by the West Virginia Geological Survey. The Headlee-Nolting summary report includes tables showing the distribution of reserves by minable coal beds as well as by counties. All coal beds averaging 2 feet or more in thickness were included in the estimate. A minimum cut-off point was established, however, and presumably no coal thinner than 18 inches was considered in calculating the reserves.

Price and others (1938) state that approximately 75,500,000,000 tons of coal in West Virginia is in beds that average 3 feet or more in thickness. The remainder of the original reserves, or approximately 41,000,000,000 tons of coal, is in the thinner beds.

In computing the reserves of West Virginia, the coal was assumed to have a specific gravity of 1.28, or a weight of 1,742 tons per acre-foot. A specific gravity of 1.28 is somewhat low, however, for typical bituminous coal in the ground. By assuming a specific gravity of 1.32, or a weight of 1,800 tons per acre-foot, which is more generally accepted as the average weight of typical bituminous coal in the ground, the West Virginia estimate would be increased 3 percent.

WYOMING

The original coal reserves of Wyoming, as estimated by Berryhill and others (Berryhill, Brown, Brown, and Taylor, 1950), totaled 121,553,850,000 tons, of which 13,234,950,000 tons is bituminous coal and 108,318,900,000 tons is subbituminous coal. According to the few available analyses, a large tonnage of coal on the eastern side of the Powder River Basin is close to the dividing line between subbituminous coal and lignite, but it is included in this estimate with reserves of subbituminous coal. The areal distribution of coal in Wyoming is shown on a map by Berryhill and others (Berryhill, Brown, Burns, and Combo, 1950).

The estimate, which shows the coal reserves of Wyoming classified by counties and by townships, was based on published and unpublished reports of the U. S. Geological Survey, on publications of the Geological Survey of Wyoming, and on records made available to the U. S. Geological Survey by mining companies, oil companies, and private individuals. Approximately 53 percent of the total area of coal-bearing rocks in Wyoming was not included in the estimate because little or no information on the coal beds in these areas was available. As more mapping and exploratory drilling programs are carried on in the coal-bearing areas in Wyoming, therefore, the estimate of reserves should be substantially increased.

The minimum thickness of coal included in the Wyoming reserve estimate was 14 inches for bituminous coal and 2½ feet for subbituminous coal. The reserves of different ranks of coal were classified according to the following thickness ranges:

Bituminous coal
More than 42 inches
28 to 42 inches
14 to 28 inches

Subbituminous coal
More than 10 feet
5 to 10 feet
2½ to 5 feet

The assumed areal extent of each coal bed was determined according to the standard U. S. Geological Survey procedures. Coal in the narrow weathered zone at the outcrop was included in the assumed area of coal occurrence, as was coal under roads and railroads. All known areas of burned coal, however, were excluded.

The coal reserves of Wyoming were classified in this estimate in the following ranges according to thickness of overburden:

0 to 1,000 feet
1,000 to 2,000 feet
2,000 to 3,000 feet

The reserves were further divided, according to the relative abundance of reliable information on which the estimates were based, into the three categories--measured, indicated, and inferred--established according to the standard procedures of the U. S. Geological Survey.

In calculating the reserve estimate, the bituminous coal in Wyoming was assumed to have a specific gravity of 1.32, or a weight of 1,800 tons per acre-foot, and the subbituminous coal was assumed to have a specific gravity of 1.3, or a weight of 1,770 tons per acre-foot.

The accompanying table shows the estimated original coal reserves of Wyoming classified according to rank of coal, thickness of bed, thickness of overburden, and relative abundance of reliable information.

Estimated original coal reserves of Wyoming
(In thousands of short tons)

Overburden	Thickness of bed	Measured reserves	Indicated reserves	Inferred reserves	Total
		Bituminous coal			
0 to 1,000 ft.	(14 to 28 in.	24,400	446,070	57,050	527,520
	(28 to 42 in.	149,610	680,760	82,900	913,270
	(42 in.+	1,512,910	2,180,750	593,460	4,287,120
	Total	1,686,920	3,307,580	733,410	5,727,910
1,000 to 2,000 ft.	(14 to 28 in.	4,860	143,590	276,060	424,510
	(28 to 42 in.	21,840	332,310	425,770	779,920
	(42 in.+	318,840	1,507,040	967,600	2,793,480
	Total	345,540	1,982,940	1,669,430	3,997,910
2,000 to 3,000 ft.	(14 to 28 in.	---	58,700	294,480	353,180
	(28 to 42 in.	---	98,350	448,410	546,760
	(42 in.+	30,140	1,043,580	1,535,470	2,609,190
	Total	30,140	1,200,630	2,278,360	3,509,130
Total		2,062,600	6,491,150	4,681,200	13,234,950
		Subbituminous coal			
0 to 1,000 ft.	(2½ to 5 ft.	7,890	6,503,920	7,358,730	13,870,540
	(5 to 10 ft.	70,960	9,151,400	15,428,480	24,650,840
	(10 ft.+	1,473,670	15,561,830	35,148,700	52,184,200
	Total	1,552,520	31,217,150	57,935,910	90,705,580
1,000 to 2,000 ft.	(2½ to 5 ft.	---	737,660	2,871,010	3,608,670
	(5 to 10 ft.	5,070	673,090	9,499,040	10,177,200
	(10 ft.+	1,780	363,600	498,300	863,680
	Total	6,850	1,774,350	12,868,350	14,649,550
2,000 to 3,000 ft.	(2½ to 5 ft.	---	281,540	810,180	1,091,720
	(5 to 10 ft.	---	266,210	1,215,630	1,481,840
	(10 ft.+	---	171,830	218,380	390,210
	Total	---	719,580	2,244,190	2,963,770
Total............		1,559,370	33,711,080	73,048,450	108,318,900
Total, both ranks		3,621,970	40,202,230	77,729,650	121,553,850

OTHER STATES

In this progress report of the U. S. Geological Survey's program for the reappraisal of the coal reserves of the United States, it has not been possible to include new appraisals for all states. For states not previously discussed, therefore, the only estimates available are those prepared by Campbell in the years prior to 1928. These have been included in tables 1 and 2 for the sake of completeness.

In calculating his estimates of original reserves, Campbell used the following minimum thicknesses for the different ranks of coal:

Bituminous coal and anthracite----	14 inches
Subbituminous coal---------------	2 feet
Lignite------------------------	3 feet

Otherwise, he included in a single category all coal to a depth 3,000 feet below the surface. Campbell based his estimates on an assumed specific gravity of 1.3, or a weight of 1,770 tons per acre-foot, for coal of all ranks.

Campbell's estimates of coal reserves were carefully prepared, but for many areas he had very little information with which to work, and in an attempt to provide a comprehensive estimate of all possible coal in the United States he made statistical allowance for the continuity of coal beds over large unmapped areas and areas concealed by glacial drift or younger rocks. In states where the coal beds have been demonstrated to be discontinuous the Campbell estimates are conspicuously high. In states where very little information on coal is available for certain areas, or where the coal-bearing rocks are concealed, the more rigid methods of calculating coal reserves now employed by the Geological Survey will also tend to reduce the Campbell estimates by excluding such areas from consideration.

Although it is recognized that, in general, the Campbell estimates are high and are subject to revision, they are included in tables 1 and 2 as originally prepared. With an active program of work in progress toward the revision of these estimates, arbitrary changes at the present time would not result in valid figures and would tend to be confusing. It is hoped that a complete, documented revision of the Campbell estimates can be completed in the near future.

ALASKA

Coal is known to occur in substantial quantities at numerous places in Alaska. Very little detailed mapping or exploration has been carried on in the coal-bearing areas, however, and only a generalized appraisal of the total coal reserves in the Territory can be made at the present time. According to an appraisal prepared in 1944 by Clyde Wahrhaftig of the Geological Survey, the total original coal reserves of Alaska were inferred to be 107,394,000,000 tons (Buch, Hendricks, and Toenges, 1947, p. 235), of which 23,800,000,000 tons is bituminous coal; 82,594,000,000 tons, subbituminous coal and lignite; and 1,000,000,000 tons, anthracite.

The coal reserves of Alaska cannot be classified by thickness of bed or overburden because of the scarcity of detailed information. Access to transportation facilities is the chief factor affecting coal-mining development in Alaska, and the reserve figures presented in the accompanying table are therefore classified by region and by accessibility to present railroads.

By January 1, 1950, the total recorded production of coal in Alaska totaled 5,621,000 tons, most of which came from the Matanuska Valley and Nenana fields on the Alaska Railroad. High costs of mining and shipping limit Alaskan coal at present to use within the Territory.

COKING-COAL RESERVES

Coke is a manufactured product, and in spite of the frequent use of the term "coking coal," there is actually little coal that can be used alone to produce coke satisfactory for metallurgical processes. Coal of medium-volatile bituminous rank is best for use in coke production, but reserves of coal of this rank are small and are rapidly being depleted. Coke that is equally satisfactory, however, can often be produced by blending together two different ranks of coal. Generally, 15 to 30 percent low-volatile coal is used in a blend with high-volatile coal that alone produces only an inferior coke. Poorly coking coal is sometimes improved by blending with such noncoking ingredients as anthracite fines, petroleum coke, or low-temperature char.

In addition to rank the basic plant constituents of a coal also seem to be important in determining the suitability of a coal for manufacturing coke, and such deleterious constituents as ash and sulfur must not be present in excessive quantities.

Most of the reserves of high-rank and high-quality coal best suited for coke production are found in the East, principally in West Virginia, Pennsylvania, Kentucky, and Virginia. In a few areas in the West, principally in Colorado, Utah, New Mexico, Oklahoma, and Arkansas, coal is produced that is satisfactory for the manufacture of coke when used in blends. The available information about reserves of such coal in the West is summarized in another report (Berryhill and Averitt, in preparation).

Because of the almost limitless possibilities of blending coals and other hydrocarbons in the manufacture of coke, and because of the certainty that the acceptable amounts of impurities in coke will be allowed to increase and coking properties to decrease as the higher-rank and higher-grade coals are depleted, it is impossible to define coking coal in precise terms. It may be possible, however, to establish certain categories of coal based on coking properties, grade, and sulfur content, conforming to ranges now regarded as acceptable for use in making coke, and to report coal reserves in these categories, but this has not as yet been done.

As low-volatile bituminous coal is a blending agent that makes possible the use of vastly larger reserves of high-volatile bituminous coal for coke production, the reserves of low-volatile coal are important in regard to present and future supplies of coking coal. The original reserves of low-volatile bituminous coal in the United States are shown in the following table, as estimated on the basis of information prepared by the Pennsylvania and West Virginia Geological Surveys and information presented by M. R. Campbell in a U. S. Geological

Estimated original coal reserves of Alaska
(In thousands of short tons)

Region	Accessible by present means of transportation	Within 40 miles of present means of transportation but not immediately available	Remote from present means of transportation	Total
Bituminous coal				
Arctic Ocean drainage..	---	---	22,000,000	22,000,000
Yukon and Kuskokwim drainage basins 1/...	---	2/	---	---
Pacific Ocean drainage and Alaska Peninsula 3/........	450,000	1,350,000	---	1,800,000
Total	450,000	1,350,000	22,000,000	23,800,000
Subbituminous coal and lignite				
Arctic Ocean drainage..	---	---	60,000,000	60,000,000
Yukon and Kuskokwim drainage basins 1/...	---	400,000	---	400,000
Pacific Ocean drainage and Alaska Peninsula 3/........	2,400,000	19,600,000	186,000	22,186,000
Total	2,400,000	20,000,000	60,186,000	82,586,000
Lignite				
Southeastern Alaska....	8,000	---	---	8,000
Anthracite				
Pacific Ocean drainage and Alaska Peninsula 3/........	----	1,000,000	---	1,000,000
Total, all ranks ...	2,858,000	22,350,000	82,186,000	107,394,000

1/ Excludes areas south of the Tanana River tributary to the Alaska Railroad and the Richardson Highway.
2/ Present, but quantity unknown.
3/ Includes areas excluded in Yukon and Kuskokwim drainage basins.

Original low-volatile bituminous coal reserves of the United States

State	Reserves (In thousands of short tons)	Percent of total reserves in state	Percent of total U. S. reserves
West Virginia..........	10,251,139	8.8	-
Pennsylvania	5,672,905	5.8	-
Maryland	4,021,500	50.0	-
Oklahoma	2,000,000	3.6	-
Arkansas	1,226,000	71.5	-
Virginia	400,000	1.8	-
Other states	934,000	-	-
Total	24,505,544	.....	1.0

Survey press release on the coal resources of the United States printed in 1928.

The total coal reserves of some of the states shown in the table may no doubt be reduced by detailed mapping and more restricted methods of calculating reserves, and the reserves of low-volatile bituminous coal will be lowered accordingly. The proportion of low-volatile coal reserves to total coal reserves can be expected to remain approximately the same, however, as both the figures just given and the figures for total reserves in tables 1 and 2 were obtained by the same methods. The value of the table lies, not in the figures cited, but in the percentages of total reserves that the figures represent.

On a tonnage basis the original reserves of low-volatile bituminous coal represent 1 percent of the total original reserves of coal of all ranks in the United States. Mining has been carried on extensively in the areas containing low-volatile coal, however, because of the desirable qualities of this rank of coal. As a semismokeless fuel with a high heat value, it has many uses in addition to the production of coke. In 1947, for example, 84,000,000 tons of low-volatile coal was mined, of which only about 25 percent was used in manufacturing coke (Fieldner, 1950, pp. 13-14).

In many areas of less desirable and less readily accessible coal in the United States, the remaining reserves are very nearly equal to the original reserves because little mining has been done. The areas of low-volatile coal, on the other hand, are rapidly being exhausted, and the remaining reserves of this coal are now much less than 1 percent of the total coal remaining in the United States, of which no more than half can be regarded as recoverable. With a more or less limited supply of low-volatile bituminous coal available, it is apparent that coking operations and metallurgical processes must soon be adjusted to permit increasing use of lower-rank coal, of which larger reserves still remain.

WORLD COAL RESERVES

Estimates of the coal reserves of the world by continents and principal producing countries, as compiled by the Fourth World Power Conference (Brown, 1948), are shown in table 3. All figures in the table are in metric tons, the standard unit for measuring coal in most countries other than the United States. One metric ton is equivalent to 1.1 short tons.

With 2,254,027 million metric tons of coal, as currently appraised, the United States appears to have 39.9 percent of the total world reserves of 5,651,920 million metric tons. By comparison, the entire North American continent appears to have 43.2 percent of the total, and Asia, including European Russia, appears to have 40.6 percent.

Table 3 gives only a very generalized comparison of the reserves in the principal coal-producing countries of the world. Because of the various methods of calculating coal reserves, the different standards of thickness and depth adopted, and the different dates for which estimates were made for different countries, the individual figures shown in the table are comparable only to the extent that they show the general magnitude of reserves in each country. In particular, the revisions in recent years of methods of calculating coal reserves by some countries, together with continued adherence to older principles by others, means that certain figures in the table are conservative and represent only immediately accessible proved coal in thick beds, whereas other figures are much more comprehensive and include total reserves in thick and thin beds regardless of quality, minability, or accessibility of the coal.

Canada provides an example of the effect of revision of methods of coal-reserves calculation. Figures published in 1913 gave Canada original reserves of 1,360,535 million metric tons of coal (Twelfth International Geological Congress, 1913). Since that time, Canadian methods have been revised, and, as a result, the reserves are now estimated as being 89,644 million metric tons (MacKay, 1947). The earlier estimate was made on general assumptions of continuity of coal beds based on few observations and included statistical allowance for all possible coal to a minimum thickness of 1 foot regardless of quality, minability, or accessibility. Present Canadian estimates include only known developed or explored coal beds which, for reasons of thickness, quality, and extraction costs, were considered economically

Table 3. --Estimated original coal reserves of the world by continents and principal coal-producing countries

Continent and country	Original reserves (In thousands of metric tons)	Percent of continent total	Percent of world total
North America:			
United States 1/	2,254,027,000	92.3	39.9
Alaska 2/	97,426,000	4.0	1.7
Canada	89,644,000	3.7	1.6
Total	2,441,097,000	100.0	43.2
Asia:			
U. S. S. R. 3/	1,200,000,000	52.2	21.2
China	1,011,000,000	44.0	17.9
India	62,143,000	2.7	1.1
Japan	16,218,000	.74	.28
Others 4/	7,563,000	.36	.12
Total	2,296,924,000	100.00	40.60
Europe:			
Germany	336,274,000	51.8	5.9
United Kingdom	172,200,000	26.5	3.1
Poland	80,018,000	12.3	1.4
Czechoslovakia	18,950,000	2.9	.35
Portugal	10,236,000	1.6	.19
Others 5/	31,134,000	4.9	.56
Total	648,812,000	100.00	11.50
Africa:			
Union of South Africa	205,395,000	99.06	3.66
Others 6/	1,930,000	.94	.04
Total	207,325,000	100.00	3.70
Australasia:			
Australia	53,100,000	99.0	0.92
Others 7/	546,000	1.0	.01
Total	53,646,000	100.0	0.93
South America:			
Chile	2,116,000	51.4	0.036
Others 8/	2,000,000	48.6	.034
Total	4,116,000	100.0	0.07
World total	5,651,920,000	......	100.00

1/ Estimate of original reserves as shown in tables 1 and 2, converted to metric tons.

2/ Estimate of original reserves as shown on page 24, converted to metric tons.

3/ Total for European Russia included with Asiatic Russia.

4/ Includes Korea, Malaya, Manchuria, and Turkey.

5/ Includes Austria, Belgium, Bulgaria, Denmark, Greece, Hungary, Italy, The Netherlands, Norway, Rumania, Sweden, and Yugoslavia.

6/ Includes Algeria, Belgian Congo, French Morocco, Madagascar, Nigeria, and Tanganyika.

7/ Includes New Zealand and New Caledonia.

8/ Includes Peru, Honduras, Colombia, and Brazil.

minable in 1946. Reserves for most other countries shown in table 3 relate to all coal in the ground, irrespective of quality, minability, or accessibility, and many of these figures will no doubt be reduced in the future as more detailed information becomes available and more restricted methods of calculating reserves are adopted.

RELATION OF COAL IN THE UNITED STATES TO OTHER FORMS OF ENERGY

Coal supplied 39.3 percent of the energy produced for heat, light, and power in the United States in 1949. During the same year, petroleum and natural gas together contributed 53.0 percent of the energy produced (U. S. Bureau of Mines, 1950). As shown in figure 5, the percentage of total energy supplied by coal has decreased steadily since 1900, when, prior to the general use of petroleum and natural gas, 90 percent of the energy used in the United States was supplied by coal. Since that time, an increase in the use of the other two fuels, because of their availability and convenience, has been accompanied by a decrease in the percentage of energy produced by coal. This trend is not expected to continue indefinitely. As the Nation's reserves of petroleum and natural gas diminish, coal will become increasingly important by filling many of the energy requirements now supplied by other fuels. Even assuming future competition from atomic sources, coal is an important factor in the national fuel economy and is likely to remain so for many years.

The decrease in the percentage contribution of coal to the total consumption of mineral fuels in the United States has not been accompanied by a comparable decrease in the actual production of coal. On the contrary, an all-time record was established in 1947 when 630,623,722 tons of coal was produced. The trend of high production of coal during World War II and the years immediately following is similar, however, to the trend that took place during and after World War I, when the previous record was set in 1918 with a production of 579,385,820 tons of coal. The fact that the 1947 figures for record production is so close to the 1918 figure seems to suggest that the maximum figure for annual coal production in the United States will be about 600,000,000 tons as long as petroleum and natural gas are available in quantity as sources of energy. No sharp rise from this established figure can be expected until coal is drawn upon as a source of liquid as well as solid fuels.

Estimates of coal reserves cannot readily be compared with estimates of petroleum and natural gas reserves, because the differences in the mode of occurrence of these fuels necessitate different methods of calculating reserves. Coal occurs in stratified deposits in sedimentary rocks, and the beds maintain a fairly uniform thickness over relatively large areas. From geologic observations made at the outcrops of coal beds, in mines and prospect pits, and from evidence supplied by drilling operations, the total quantity of coal in the ground can be estimated with reasonable accuracy. In the same way, estimates of total reserves of bituminous sandstone and oil shale can be obtained because these substances also occur in stratified deposits of measurable thickness and lateral extent.

Liquid petroleum and natural gas, on the other hand, are mobile substances that move through minute openings in the rocks and accumulate only where geologic relations provide traps that prevent further migration. As a great variety of structural and stratigraphic relations create such traps, the total number of traps existing in the widespread thick sequences of sedimentary rocks cannot be predicted accurately, nor can the ultimate amount of recoverable oil or gas contained in these traps be ascertained. Only proved reserves, or reserves in developed areas, can be estimated with any certainty for petroleum and natural gas, and consequently the estimates must be changed annually to accord with new discoveries and with production.

Despite the recognized difficulty of comparing reserve estimates for various types of mineral fuels, it is desirable, nevertheless, to indicate the relation of coal reserves to the total mineral-fuel reserves of the United States. In order to show reserves of the several different fuels on as nearly similar bases as possible, two separate tables (tables 4 and 5) are presented, each representing a major point of view in regard to reserve estimates.

Table 4 shows the total ultimately recoverable mineral-fuel reserves of the United States as of January 1, 1950. The coal reserve estimate of 1,212.79 billion tons shown in this table was obtained from tables 1 and 2. It includes measured, indicated, and inferred reserves of coal in both thick and thin beds, under light and heavy overburden.

Several attempts have been made to obtain comparable figures for petroleum and natural gas reserves. These attempts have been based on the assumption that the total volume of marine sedimentary rock in the United States within range of exploration by drilling will yield petroleum and natural gas in amounts proportional to the yields obtained from the volume of rock explored thus far. Although no special accuracy is claimed for figures derived by these methods, the estimates based on currently available data are in good agreement. Weeks (1948, p. 1094) estimated the original, potentially recoverable reserves of petroleum in the United States, excluding the continental shelves, to be 110 billion barrels, and Pratt (Fanning, 1950, p. 151) estimated the amount to be 100 billion barrels. Using the same methods, Terry (Fanning, 1948, p. 149) estimated the original, potentially recoverable reserves of natural gas in the United States to be 400 trillion cubic feet. Considering the additional quantities of oil present in the continental shelves, and the ever present possibility of future additions to petroleum and natural gas reserves beyond those allowed for by a statistical analysis of currently available data, it is likely that the figures are too small rather than too large. They are, however, of the order of magnitude required for a proper comparison of oil and gas reserves with total coal reserves.

The figures derived by Weeks, Pratt, and Terry are, of course, intended to represent total ultimately recoverable original reserves; that is to say, past production, present proved reserves, and assumed future discoveries. To make them comparable with the figure for total ultimately recoverable coal reserves as of January 1, 1950, they must be reduced to allow

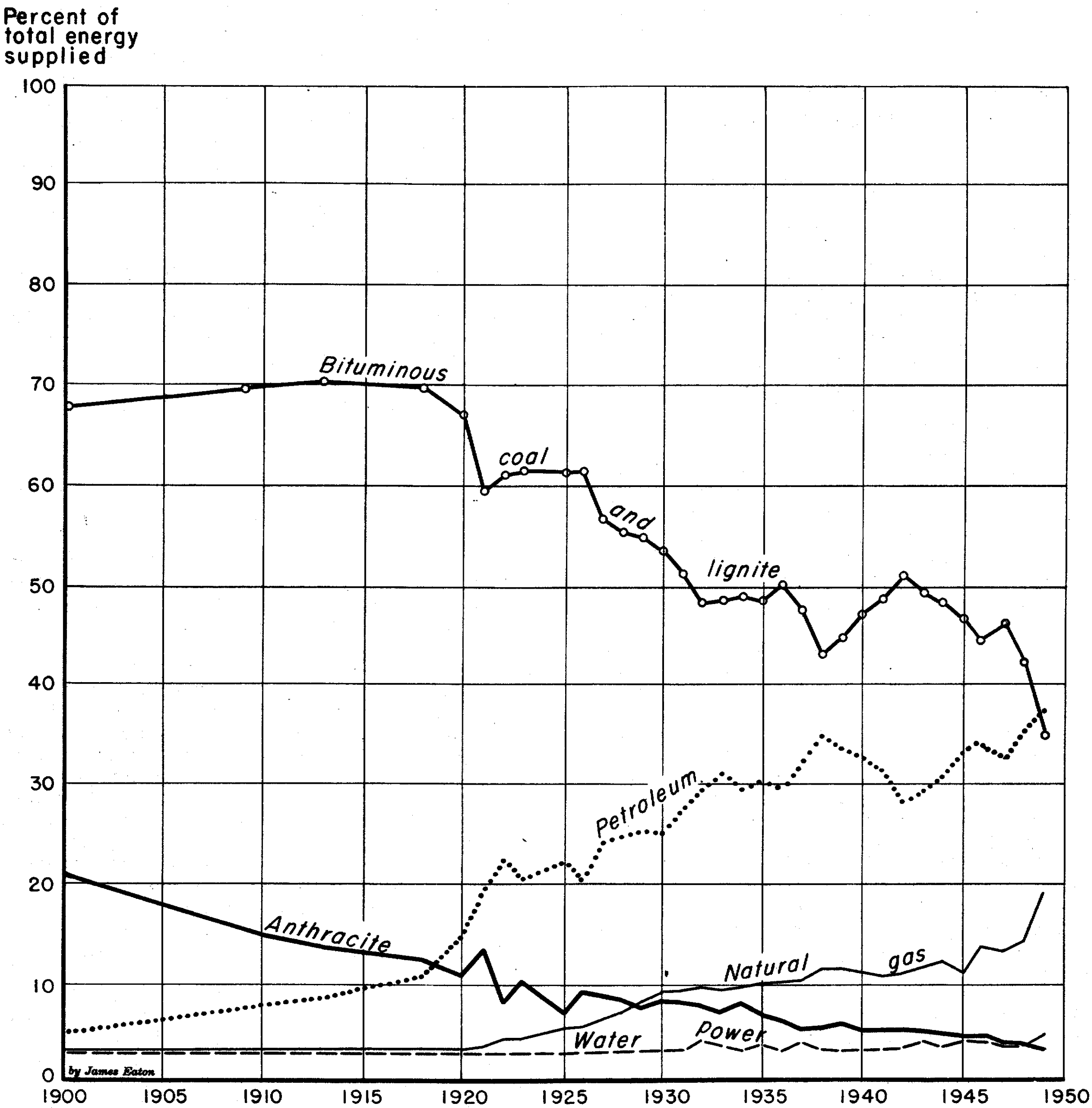

Figure 5.- Percentage of total energy supplied by mineral fúels and water power, 1900 - 1949. (Data from Bureau of Mines Minerals Yearbooks.)

for production to January 1, 1950. The figure used in table 4 of 61.07 billion barrels for ultimately recoverable petroleum reserves as of January 1, 1950, was obtained by subtracting the total recorded production of petroleum to January 1, 1950, from Pratt's estimate of 100 billion barrels. Similarly, the figure of 277.64 trillion cubic feet for ultimately recoverable natural gas reserves as of January 1, 1950, was obtained by subtracting the total recorded production of natural gas to January 1, 1950, from Terry's estimate of 400 trillion cubic feet.

Table 5, which is prepared on a more conservative basis than table 4, shows what is here termed the total assured recoverable mineral-fuel reserves of the United States, as of January 1, 1950. The estimates of 28.38 billion barrels of petroleum and 180.38 trillion cubic feet of natural gas shown in table 5 represent proved reserves as currently appraised by the American Petroleum Institute and the American Gas Association (Oil and Gas Journal, 1950). To correspond with these estimates, an estimate for coal reserves is included that is intended to represent only measured and indicated reserves of coal in beds 28 inches or more thick under less than 2,000 feet of overburden. The figure of 363.85 billion tons for coal reserves in this restricted category was derived from a consideration of the reserve estimates for Michigan, Montana, New Mexico, North Carolina, and Wyoming, for which the reserves of coal have been classified according to thickness of bed and overburden. On an average in these States, the measured and indicated reserves of coal in beds 28 inches or more thick under less than 2,000 feet of overburden total roughly 30 percent of the total coal reserves. This percentage was therefore applied to the figure for total recoverable coal reserves of the United States shown in table 4 to obtain the estimate for assured coal reserves shown in table 5. A further study of the same five States indicates that approximately half the assured coal reserves, or 15 percent of the total coal reserves, can be regarded as measured reserves of coal in beds 28 inches or more thick under less than 2,000 feet of overburden.

According to tables 4 and 5, the reserves of coal in the United States, when compared on a B. t. u. basis, represent 87.43 percent of the total ultimately recoverable mineral-fuel reserves, or 83.06 percent of the total assured recoverable mineral-fuel reserves. It is interesting to note that these two figures are so nearly the same.

LIFE EXPECTANCY OF UNITED STATES FUEL RESERVES

Because of the many imponderable factors to be taken into consideration, it is impossible to estimate the life expectancy of fuel reserves in the United States with any degree of accuracy. Although the considerable annual increase in the per-capita use of energy in this country may be readily observed, it is doubtful that the rate of increase in population and in the use of energy can be extrapolated with sufficient reliability, or far enough into the future to afford a sound basis for predicting life expectancy of fuel reserves. Moreover, the trend toward increased use of energy may be offset in part by the trend toward greater efficiency in the production and use of fuel, the large amount of petroleum available on other continents for import into the United States, and the likelihood that new sources of fuel and power will be developed in the future.

Appraisal of the life expectancy of any individual fuel is further complicated by the fact that most fuels can be used interchangeably, and at most installations the choice of fuel is determined largely by cost. The present relative increase in use of petroleum and natural gas, which is due to the present abundance and comparative economy of these convenient fuels, will, therefore, continue as long as new petroleum and natural gas fields are discovered in the United States and as long as imported supplies of petroleum are available in domestic markets. On the other hand, as petroleum and natural gas ultimately become less abundant, and hence more expensive than coal, many users of these fuels will convert to coal. Thus, long before petroleum and natural gas reserves in the United States are diminished, a gradual increase in the use of coal may be expected. This period of transition may be greatly lengthened by utilization of imported supplies of petroleum, and it will be obscured by fluctuations in the economic cycle and by irregularities in the rate of discovery of new petroleum and natural gas fields. In all probability, only the future historian looking backward will be able to say when the return to more general use of coal began. Because the life expectancy of petroleum and natural gas reserves will be greatly extended as the relative use of coal and other fuels is increased, and because of the possibility of additions to petroleum and natural gas reserves not allowed for in this report, an estimate of the life expectancy of any of these fuels is subject to serious question.

The life expectancy of coal reserves is influenced by several additional factors. At present only a small percentage of the total coal reserves in the United States can be said to be accurately measured or definitely indicated to be present in the ground. The remainder is merely inferred to be present from available information on the distribution and thickness of coal beds and coal-bearing rocks, and its true quantity remains to be verified. The interim appraisal of coal reserves included in this report is therefore subject to considerable modification. Furthermore, the recoverable reserves of coal are assumed in this report to be only half the total reserves in the ground. This factor is based on the past average experience in a number of mining districts. The recovery from a few efficiently run mines, however, is much higher, and it is probable that in the future the average recovery in mining will improve. Also, many thin beds, not now considered to be minable, may ultimately be included as recoverable reserves if underground gasification techniques, now in the experimental stage, can be improved.

The manner in which coal is used is perhaps the largest indeterminable factor that enters into any consideration of the life expectancy of coal reserves. Viewing future uses of coal over a long period, it is apparent that with the slow return to coal, the uses at first will be the same as at present. As noted by Wrather and others (1950), however, the United States is committing itself to a liquid- and gaseous-fuel economy, and ultimately coal will serve as one of the sources of these fuels in addition to filling the

Table 4.-- Total ultimately recoverable mineral-fuel reserves of the United States, January 1, 1950

Type of mineral fuel	Ultimately recoverable reserves and average annual production (Coal in billions of short tons; petroleum, bitumen from bituminous sandstone, and oil from oil shale in billions of barrels; and natural gas in trillions of cubic feet)		Ultimately recoverable reserves and average annual production (In quadrillions of B.t.u.) 1/		Ratio of ultimately recoverable reserves, as currently appraised, to average annual production, 1940-50	Percent of total ultimately recoverable mineral-fuel reserves on B.t.u. basis, January 1, 1950
	Ultimately recoverable reserves, January 1, 1950	Average annual production, 1940-50	Ultimately recoverable reserves, January 1, 1950	Average annual production, 1940-50		
Coal:						
Bituminous coal	616.32	0.544	16,024.32	14.14	------	55.14
Subbituminous coal	233.85	.007	4,443.15	.13	------	15.29
Lignite	355.73	.003	4,766.78	.04	------	16.40
Anthracite and semianthracite .	6.89	.057	175.01	1.45	------	.60
Total coal, all ranks	2/ 1,212.79	0.611	25,409.26	15.76	1612	87.43
Petroleum	3/ 61.07 ?	1.780	366.42 ?	10.68	34 ?	1.26
Bitumen from bituminous sandstone	4/ 1.25	Negligible	7.50	Negligible	------	.03
Oil from oil shale	5/ 500.00	Negligible	3,000.00	Negligible	------	10.32
Natural gas	6/ 277.64 ?	4.710	277.64 ?	4.71	59 ?	.96

1/ Reserves and production figures converted to B.t.u. according to the following heat values: anthracite, 12,700 B.t.u. per pound; bituminous coal, 13,000 B.t.u. per pound; subbituminous coal, 9,500 B.t.u. per pound; lignite, 6,700 B.t.u. per pound; petroleum, bitumen from bituminous sandstone, and oil from oil shale, 6,000,000 B.t.u. per barrel; and natural gas, 1,000 B.t.u. per cubic foot.

2/ Tables 1 and 2, pp. 4 and 5.

3/ Recoverable reserves of petroleum remaining after subtracting petroleum production to January 1, 1950, from original petroleum reserves of 100 billion barrels, as estimated by W. E. Pratt in Our oil resources, second edition, edited by L. M. Fanning, McGraw-Hill Book Company, New York, 1950. Figure does not include continental shelves.

4/ Fifty percent of estimated measured, indicated, and inferred reserves of bitumen from bituminous sandstone in deposits near Vernal and Sunnyside, Utah; Casmalia, Santa Cruz, Edna, Sisquac, Sulphur Mountain, and San Ardo, Calif.; and Uvalde, Tex.

5/ Fifty percent of reserves of oil in oil shale deposits having an average content of 15 barrels of oil per ton, as estimated by D. C. Duncan, U. S. Geological Survey. Personal communication.

6/ Recoverable reserves of natural gas remaining after subtracting natural gas production to January 1, 1950, from original natural gas reserves of 400 trillion cubic feet, as estimated by L. F. Terry in Our oil resources, first edition, edited by L. M. Fanning, McGraw-Hill Book Company, New York, 1945. Figure does not include continental shelves.

Table 5.--Total assured recoverable mineral-fuel reserves of the United States, January 1, 1950

Type of mineral fuel	Assured recoverable reserves and average annual production (Coal in billions of short tons; petroleum, bitumen from bituminous sandstone, and oil from oil shale in billions of barrels; and natural gas in trillions of cubic feet)		Assured recoverable reserves and average annual production (In quadrillions of B.t.u.) 1/		Ratio of assured recoverable reserves, as currently appraised, to average annual production 1940-50	Percent of total assured recoverable mineral-fuel reserves on B.t.u. basis, January 1, 1950
	Assured recoverable reserves, January 1, 1950	Average annual production, 1940-50	Assured recoverable reserves, January 1, 1950	Average annual production, 1940-50		
Coal:						
Bituminous coal	2/ 184.90	0.544	4,807.40	14.14	------	52.38
Subbituminous coal	2/ 70.16	.007	1,333.04	.13	------	14.53
Lignite	2/ 106.72	.003	1,430.05	.04	------	15.58
Anthracite and semianthracite .	2/ 2.07	.057	52.58	1.45	------	.57
Total coal, all ranks	363.85	0.611	7,623.07	15.76	484	83.06
Petroleum	3 4/ 28.38	1.780	170.28	10.68	16	1.86
Bitumen from bituminous sandstone	5/ .65	Negligible	3.90	Negligible	------	.04
Oil from oil shale	6/ 200.00	Negligible	1,200.00	Negligible	------	13.08
Natural gas	7/ 180.38	4.710	180.38	4.71	38	1.96

1/ Reserves and production figures converted to B.t.u. according to the following heat values: anthracite, 12,700 B.t.u. per pound; bituminous coal, 13,000 B.t.u. per pound; subbituminous coal, 9,500 B.t.u. per pound; lignite, 6,700 B.t.u. per pound; petroleum, bitumen from bituminous sandstone, and oil from oil shale, 6,000,000 B.t.u. per barrel; and natural gas, 1,000 B.t.u. per cubic foot.

2/ Thirty percent of reserves as shown in table 1, determined by a consideration of five states for which reserve estimates have been classified by thickness of bed and overburden. The estimate is intended to show reserves of measured and indicated coal in beds at least 28 inches thick under no more than 2,000 feet of overburden.

3/ Includes 3.73 billion barrels of natural gas liquids.

4/ Estimate by the American Petroleum Institute, as reported in the Oil and Gas Journal, vol. 48, no. 45, pp. 56-57, March 16, 1950.

5/ Fifty percent of measured and indicated reserves of bitumen from bituminous sandstone in deposits near Vernal and Sunnyside, Utah; Casmalia, Santa Cruz, and Edna, Calif.; and Uvalde, Tex.

6/ Sixty percent of measured reserves of oil shale containing 15 barrels of oil per ton, as estimated by Carl Belser in Oil shale resources of Colorado, Utah, and Wyoming, American Institute of Mining and Metallurgical Engineers Technical Publication 2358, 1948.

7/ Estimate by the American Gas Association, as reported in the Oil and Gas Journal, vol. 48, no. 45, pp. 56-57, March 16, 1950.

requirements for solid fuel. If such conversion of coal becomes general, the needs for coal will be enormous, for 50 percent of the potential energy in coal is lost in the conversion to liquid fuel.

Although it is thus impossible to predict the life expectancy of the several mineral fuels, the ratios between the currently estimated recoverable reserves of each fuel and the present annual rates of production provide figures that are somewhat more meaningful for comparative purposes than the reserve figures alone. As shown in table 4, the ultimately recoverable reserves of coal in the United States are 1,612 times the average annual production during the period 1940 to 1950; the ultimately recoverable reserves of petroleum are 34 times the average annual production; and the ultimately recoverable reserves of natural gas are 59 times the average annual production.

Table 5, which is identical in arrangement with table 4, but based more conservatively on appraisals of proved or definitely assured reserves, shows that the assured recoverable reserves of coal in the United States are 484 times the recent average annual production; the assured reserves of petroleum are 16 times the average annual production; and the assured reserves of natural gas are 38 times the average annual production.

From a consideration of the probable trends in the use of these fuels it is apparent that their probable life expectancy is quite different from the simple ratios of present production as compared to reserves. Petroleum and natural gas reserves certainly have a much longer life expectancy than the ratios indicate, and coal reserves, conversely, have a shorter life expectancy.

CONCLUSIONS

As appraised in this interim report, the coal reserves of the United States remaining in the ground on January 1, 1950, total 2,425,566 million tons, half of which can be regarded as ultimately recoverable. This total is made up of a number of individual state estimates, some of which were prepared as long ago as 1908, others of which were prepared in 1949. The older estimates were prepared on a highly generalized basis and were intended to represent total possible reserves in both thick and thin beds and under light and heavy overburden. These older estimates are useful only for the purpose of comparing the total reserves of one state with another. The more recent estimates have been prepared on a more conservative basis than the older estimates and tend to be considerably smaller. A reduction of the total reserve figure reported is therefore in prospect, though the reserves still will appear abundant.

The newer state estimates prepared by the U. S. Geological Survey, five of which are presented in this report, provide additional data on coal reserves in individual counties and smaller geographic units and in categories for each rank of coal according to the thickness of the beds, their depth below the surface, and the abundance of reliable information on which the appraisals were made. The newer state estimates thus have considerable usefulness in planning for the development of the coal and the coal-bearing regions.

Extrapolating from the small amount of detailed coal reserve data now available, it appears that roughly 15 percent of the total estimated reserves given in tables 1 and 2 can be regarded as measured reserves in beds 28 inches or more thick under less than 2,000 feet of overburden; that an additional 15 percent can be regarded as indicated reserves within the same limits of thickness and depth below the surface; and that the remaining 70 percent is inferred reserves, reserves in thin beds, or reserves 2,000 to 3,000 feet below the surface. The large percentage of inferred reserves obviously includes some coal in thick beds, which for lack of detailed information cannot be appraised quantitatively. These percentages are at best only rough approximations based on insufficient data and are subject to change as new work is completed. Nevertheless, they serve to indicate the present state of knowledge of the Nation's coal reserves and point to the need for additional geologic mapping, exploration, and appraisal.

On a B. t. u. basis, the total ultimately recoverable reserves of coal as appraised on January 1, 1950, represent 87 percent of the total ultimately recover able fuel resources of the United States. By comparison, the assured recoverable reserves of coal represent 83 percent of the total assured recoverable reserves of all fuels. Although petroleum and natural gas now contribute more to the national fuel needs than coal, this trend eventually will be reversed as the smaller reserves of petroleum and natural gas become depleted. The total ultimately recoverable reserves of coal as of January 1, 1950, are 1,612 times the average annual production during the period 1940 to 1950. Assuming a great increase in coal production, these reserves still will last many generations. On any basis of analysis the coal reserves of the United States are very large by comparison with all other known available sources of heat, light, and power and give comfortable assurance that the future fuel needs of the Nation can be met in any contingency.

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