COAL

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ABSTRACT OF CONCLUSIONS

The estimated coal resources of the United States remaining in the ground as of January 1, 1972, totaled 3,224 billion tons. Of this large total, 1,581 billion tons, or 49 percent, is classed as identified, and 1,643 billion tons, or 51 percent, is classed as hypothetical.

Stripping coal resources remaining in the ground as of January 1, 1968, totaled 118 billion tons, or about 7.5 percent of the identified resources.

World coal resources are estimated to total 16,830 billion tons, of which 9,500 billion tons is classed as identified, and 7,330 billion tons is classed as hypothetical. The United States contains about one-fifth of estimated total world resources.

On a uniform Btu basis, U.S. coal resources are larger than the combined domestic resources of petroleum, natural gas, oil shale, and bituminous sandstone. The prolonged future need for energy in ever-increasing quantities, and the prospect of decreasing availability of and increased prices for petroleum and natural gas, have focused very sharp attention on coal as an alternative source of synthetic gas, liquid fuels, and lubricants.

INTRODUCTION

Coal is widespread and abundant in the United States. Coal-bearing rocks underlie about 13 percent of the land area of the 50 States, and are present in varying amounts in parts of 37 States (Trumbull, 1960; Barnes, 1961). The ready availability of coal has contributed substantially to the growth and industrial development of the nation.

On any basis of analysis, U.S. resources of coal are larger than the combined resources of petroleum, natural gas, oil shale, and bituminous sandstone, but use of coal lags behind use of both petroleum and natural gas because these two fuels are cleaner to burn and easier to handle. In spite of this handicap, annual coal production in the United States ranges typically from 500 to 600 million tons. About 10 percent of the annual production is exported, primarily to Japan, Canada, and western Europe.

Of coal consumed annually in the United States, about 62 percent is used in the production of electric power, 20 percent is used by the steel industry, 16 percent by the manufacturing industry, and 2 percent for all other purposes. Coal is also of great future value and importance as a subsidiary source of synthetic gas, liquid fuels, and lubricants.

ENVIRONMENT OF COAL ACCUMULATION

Coal is the compressed and altered residue of plants that grew in ancient fresh- or brackish-water swamps. As the plant remains accumulated they were transformed into peat; later they were altered by diagenesis (chemical and physical changes occurring before they became solidified), and still later by metamorphism (chemical and physical changes brought about by pressure and heat after they became solidified). Coal contains widely varying amounts of sand, silt, and mud that was washed into the peat swamps, and this admixed sediment forms the bulk of the ash of burned coal. The physical and chemical properties of coal and the coalification process have been described in considerable detail by Schopf (1948; 1956) and by Dapples and Hopkins (1969).

The accumulation of peat requires a humid climate to support a rich growth of vegetation, and a high water table to permit prolonged accumulation of plant material in a reducing environment (See "Peat," this volume). Most of the large peat deposits of Pennsylvanian age that were the precursors of coal mined extensively in the Eastern and Central United States were formed near sea level—some in estuaries or coastal lagoons, others on large deltas or many coalescing deltas, others on low-lying, broad coastal plains. These features form characteristically in areas of gentle downwarping of the sea floor marginal to the edges of an eroding landmass. This topographically low position in an area of gentle downwarping permitted periodic transgressions of the sea. Some thick coal beds of very wide areal extent required a very large and wide coastal plain, a prolonged optimum rate of plant growth and accumulation, a slow rate of subsidence, and an equally slow encroachment of the sea over periods measured in centuries.

The transgressive sea ultimately covered the peat-forming swamp and terminated plant growth. The eroding landmass continued to supply sand, silt, and mud to the sea, and this material settled in layers over the submerged peat swamp. In time, depending in length on the rate of sedimentation, the depth of the transgressive sea, and the rate of subsidence, this sedimentary material built up new deltas, lagoons, and coastal plains conducive to the development of new, younger peat-forming swamps.

This sequence of deposition was repeated many times by intermittent downwarping alone, but the sequence might have been prolonged, shortened, or terminated at any time by relatively minor movements of land relative to the sea floor. In the very delicate balance between sedimentation, subsidence, and uplift of the land, the sea also regressed from time to time. Peat swamps obviously formed during the regressive phase of the cycle, but these were subject to oxidation and are less commonly preserved. These cyclic repetitions of the conditions allowing the formation of coal are documented in many of the world's coal fields, but rarely as strikingly as in a sequence of several thousands of feet of sedimentary rock in West Virginia that contains 117 coal beds of sufficient geologic and economic interest to have been described and named.

Weight of the overlying sedimentary rock, heat produced by depth of burial, structural deformation, and time all contribute to the progressive compaction and devolatilization of peat to form the higher ranks of coal, which are discussed below. A subsequent major uplift of the land relative to the sea has raised the U.S. coal fields to their present positions, exposing them to erosion and to view, thereby permitting study and mine development.

RANK OF COAL

Coal is classified by rank according to the percentage of fixed carbon and heat content, calculated on a mineral-matter-free basis. As shown in figure 15, the percentage of fixed carbon and the heat content increase from lignite to low-volatile bituminous coal as the percentages of volatile matter and moisture decrease. These changes are primarily the result of depth and heat of burial, compaction, time, and structural deformation. Rank is thus a way of expressing the progressive metamorphism of coal. It is quite independent of grade, which is a way of expressing quality.

As coals of different rank are adapted to different uses, rank is a major basis of differentiation in coal-resource calculations. In accompanying tables and figures, the coal resources are expressed in short tons. If arithmetic adjustments were made for the contained heat values, the distribution patterns would be changed somewhat because of the lower heat values of lignite and subbituminous coal.

GRADE OF COAL

Coal is classified by grade largely according to the content of ash, sulfur, and other deleterious constituents. Thus far in work on coal resources, a preliminary classification on the basis of sulfur

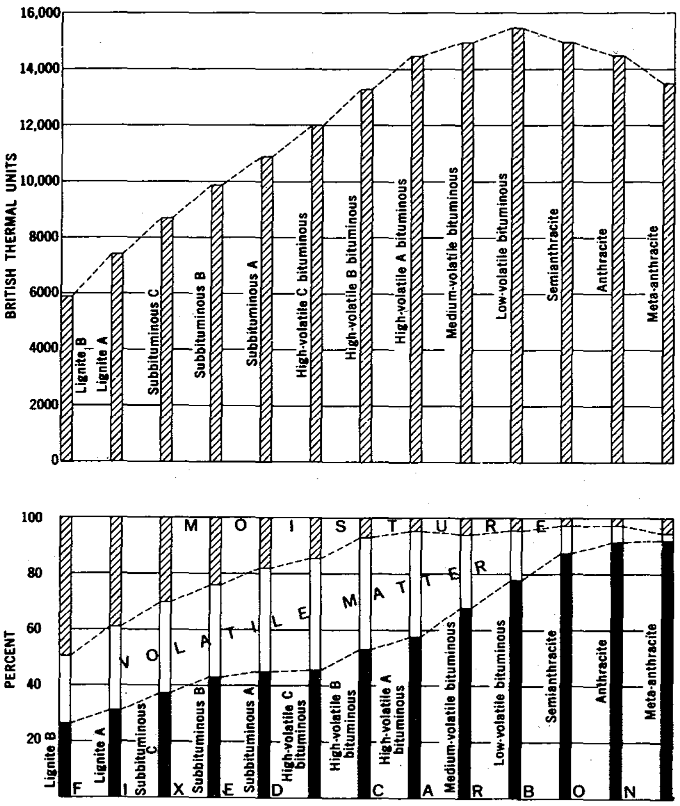

FIGURE 15.—Comparison on moist, mineral-matter-free basis of heat values and proximate analyses of coal of different ranks.

content has been made, but classification on the basis of ash content has not been made, because ash is a more highly variable component than sulfur. In recent years, information on trace elements in coal has increased somewhat, but classification according to trace-element content is not yet possible.

SULFUR

Sulfur is an undesirable element in coal. It lowers the quality of coke and of the resulting iron and steel products. It contributes to corrosion, to the formation of boiler deposits, and to air pollution. Its presence in spoil banks inhibits the growth of vegetation. As sulfuric acid, it is the main deleterious compound in acid mine waters, which contribute to stream pollution.

The sulfur content of coal in the United States ranges from 0.2 to about 7.0 percent, but the average in all coal is 1.0–2.0 percent. Most of the sulfur, perhaps 40–80 percent, occurs as a constituent of pyrite and marcasite (FeS_2). The remainder occurs as hydrous ferrous sulfate ($FeS_4 \cdot 7H_2O$), derived by weathering of pyrite, as gypsum ($CaSO_4 \cdot 2H_2O$), and as organic sulfur in combination with the coal-forming vegetal material (Walker and Hartner, 1966).

The percentage of sulfur and of pyritic sulfur is highest in bituminous coals of Pennsylvanian age in the Appalachian and Interior coal basins. The percentage is relatively low, generally less than 1 percent, in subbituminous coal and lignite of the Rocky Mountain and Northern Great Plains regions. This relation is shown clearly in table 26.

TABLE 26.—*Distribution, in percent, of identified*[1] *United States coal resources according to rank and sulfur content*[2]

Rank	Sulfur content (in percent) Low 0–1	Medium 1.1–3.0	High 3+
Anthracite	97.1	2.9	---
Bituminous coal	29.8	26.8	43.4
Subbituminous coal	99.6	.4	---
Lignite	90.7	9.3	---
All ranks	65.0	15.0	20.0

[1]Identified resources: Specific, identified mineral deposits that may or may not be evaluated as to extent and grade, and whose contained minerals may or may not be profitably recoverable with existing technology and economic conditions.
[2]From DeCarlo, Sheridan, and Murphy (1966).

The conspicuously large percentage of low-sulfur coal in the United States, shown on the last line of table 26, is primarily due to the fact that the resources of low-sulfur subbituminous coal and lignite concentrated in the Rocky Mountain and Northern Great Plains regions represent about 54 percent of total identified resources.

RESEARCH ON REMOVAL OF SULFUR

Pyrite and marcasite have a high specific gravity, and most of this material can be removed from coal by various washing and cleaning procedures. The other forms of sulfur have lower specific gravities and are more intimately mixed with the coal, and consequently are less easily removed. Between 60 and 65 percent of all coal mined in the United States is cleaned to remove pyritic and inert material before use. However, in spite of such large-scale cleaning, the average sulfur content of all coal used in the United States is still nearly 2 percent.

Current efforts to reduce the sulfur content of coal and of flue gas take many forms:

1. Much research is in progress on methods to remove SO_2 and SO_3 from flue gas. This can be done by several well-known chemical processes, and the technical problems inherent in the large-scale commercial application of chemical processes are likely to be solved in the near future.
2. Meanwhile, the search for low-sulfur coal has

been intensified, particularly in the Eastern States, and the use of lower-sulfur coal has been increased. A few older coal-burning utility plants in the Midwest have converted from high-sulfur local coal to low-sulfur Rocky Mountain coal. This substitution has required payment of transportation costs of \$3–\$5 per ton, and acceptance of the lower heat content of Rocky Mountain coal. Such high transportation costs obviously will intensify research efforts mentioned in item 1.

3. Much research is in progress on methods to produce a high-Btu, sulfur-free gas from coal. This is also a technical possibility soon to be realized. It has the multiple advantages of lowering the costs of long-distance transportation of energy, of eliminating the sulfur problem, of augmenting declining resources of natural gas, of reducing dependence on foreign sources of oil and gas, and ultimately permitting use of high-sulfur eastern coal.
4. Research on improved methods of producing electric power by nuclear fission and fusion is continuing.

These varied avenues of approach suggest that the amount of sulfur released to the atmosphere by the burning of coal will soon be greatly reduced.

MINOR ELEMENTS IN COAL

Coal contains small quantities of virtually all metallic and nonmetallic elements, that were introduced into the coal bed in one or all of four different ways:

1. As inert material washed into the coal swamp at the time of plant accumulation.
2. As a biochemical precipitate from the swamp water.
3. As a minor constituent of the original plant cells.
4. As a later addition, introduced after coal formation, primarily by ground water moving downward and laterally.

When coal is burned, most of these elements are concentrated in the coal ash, but a few of the more volatile elements are emitted into the atmosphere. Coal ash is composed largely of the oxides of Si, Al, Fe, Ca, Mg, K, Na, and S, which typically make up 93–98 percent of the total weight of the ash (Abernethy and others, 1969a). The remaining few percent of coal ash is made up of small individual amounts of many other elements, which differ in variety and quantity in different areas and beds. These elements are generally measured in parts per million or billion, and for this reason are termed minor elements, although they may not be minor elements in other contexts.

The minor elements in coal are of considerable interest because some may become of future resource importance, and others may be pollutants. Most of the minor elements occur in coal in about the same concentration as their estimated concentration in the earth's crust, but 25–30 elements occur locally in greater concentration and these have received the most study. A few elements, notably U, Ge, As, B, and Be, occur locally in vastly greater concentrations than their estimated concentration in the earth's crust; others, including Ba, Bi, Co, Cu, Ga, La, Pb, L, Hg, Mo, Ni, Sc, Se, Ag, Sr, Sn, V, Y, Zn, and Zr, occur locally in appreciably greater concentrations. Other elements of interest that generally occur in lower concentrations than those listed above include Cr, Mn, P, Te, Tl, Ti, and W. It should be noted that the concentration of an element in excess of the estimated concentration in the earth's crust, although of great interest and geologic significance, does not necessarily imply an economic or paramarginal concentration, because that is determined by the concentration in typical commercial sources of the respective element.

Reports by Abernethy and Gibson (1963); Abernethy, Peterson, and Gibson (1969a, b); Zubovic (1966a, b); Zubovic, Sheffey, and Stadnichenko (1967); Zubovic, Stadnichenko, and Sheffey (1960a, b, c; 1961a, b; 1964; and 1966); and by Sun, Vasquez-Rosas, and Augenstein (1971) summarize available information concerning minor elements in coal. A selected bibliography on trace elements in coal, applicable primarily to U.S. coals, has been compiled by Averitt, Breger, Gluskoter, Swanson, and Zubovic (1972).

UNITED STATES COAL RESOURCES

The remaining coal resources of the United States as of January 1, 1972, are estimated to total 3,224 billion tons. Of this large total, 1,581 billion tons, or 49 percent, has been identified on the basis of mapping and exploration, and the remainder of 1,643 billion tons, or 51 percent, is classed as hypothetical because it has been determined by extrapolation of the data on identified resources into unmapped and unexplored areas. The distribution of this tonnage by State is given in table 27.

The figures in table 27, and in subsequent tables and figures, express resources in the ground. The recoverability in coal mining ranges from 40 to 90 percent, depending largely on the method of mining, but it is influenced by many other diverse factors such as the nature of the roof rock, joints, faults,

TABLE 27.—*Total estimated remaining coal resources of the United States, January 1, 1972*

[In millions of short tons. Figures are for resources in the ground, about half of which may be considered recoverable. Includes beds of bituminous coal and anthracite 14 in. or more thick and beds of subbituminous coal and lignite 2½ ft or more thick]

State	Identified resources [1]						Hypothetical resources [2]			Total resources
	Overburden 0–3,000 ft						Overburden 0–3,000 ft	Overburden 3,000–6,000 ft	Overburden 0–6,000 ft	Overburden 0–6,000 ft
	Estimated identified resources remaining in the ground, Jan. 1, 1972									
	Bituminous coal	Subbituminous coal	Lignite	Anthracite and semianthracite	Total	Source of estimate	Estimated hypothetical resources in unmapped and unexplored areas reasonably near the surface [3]	Estimated hypothetical resources in deeper structural basins [3]	Total estimated hypothetical resources	Total estimated identified and hypothetical resources remaining in the ground Jan. 1, 1972
Alabama	13,342	0	2,000	0	15,342	Culbertson (1964); T. A. Simpson (written commun., 1972).	20,000	6,000	26,000	41,342
Alaska	19,413	110,668	([4])	([5])	130,081	Barnes (1951; 1967)	130,000	5,000	135,000	265,081
Arizona	[6]21,246	([6])	0	0	21,246	Peirce and others (1970)[7].	0	0	0	21,246
Arkansas	1,638	0	350	430	2,418	Haley (1960)	4,000	0	4,000	6,418
Colorado	62,339	18,242	0	78	80,659	Landis (1959)	146,000	145,000	291,000	371,659
Georgia	24	0	0	0	24	Johnson (1946)[7]	60	0	60	84
Illinois	139,124	0	0	0	139,124	Simon (1965)[7]	100,000	0	100,000	239,124
Indiana	34,573	0	0	0	34,573	Spencer (1953)	22,000	0	22,000	56,573
Iowa	6,509	0	0	0	6,509	Landis (1965)	14,000	0	14,000	20,509
Kansas	18,674	0	([8])	0	18,674	Schoewe (1952; 1958)[7]	4,000	0	4,000	22,674
Kentucky	64,842	0	0	0	64,842	Huddle and others (1963).	52,000	0	52,000	116,842
Maryland	1,158	0	0	0	1,158	Averitt (1969)	400	0	400	1,558
Michigan	205	0	0	0	205	Cohee and others (1950).	500	0	500	705
Missouri	31,014	0	0	0	31,014	Robertson (1971)[7]	18,200	0	18,200	49,214
Montana	2,299	131,855	87,521	0	221,675	Combo and others (1949; 1950)[7].	157,000	0	157,000	378,675
New Mexico	10,752	50,671	0	4	61,427	Read and others (1950)	27,000	21,000	48,000	109,427
North Carolina	110	0	0	0	110	Reinemund (1949; 1955).	20	5	25	135
North Dakota	0	0	350,630	0	350,630	Brant (1953)	180,000	0	180,000	530,630
Ohio	41,358	0	0	0	41,358	Brant and DeLong (1960).	2,000	0	2,000	43,358
Oklahoma	3,281	0	([8])	0	3,281	Trumbull (1957)	20,000	10,000	30,000	33,281
Oregon	50	284	0	0	334	R. S. Mason (written commun., 1965)[7].	100	0	100	434
Pennsylvania	56,759	0	0	20,510	77,269	Reese and Sisler (1928); Arndt and others (1968)[7].	[9]10,000	0	10,000	87,269
Rhode Island	0	0	0	([10])	----	Toenges and others (1948).	0	0	0	----
South Dakota	0	0	2,031	0	2,031	D. M. Brown (1952)	1,000	0	1,000	3,031
Tennessee	2,572	0	0	0	2,572	Luther (1959; written commun., 1965).	2,000	0	2,000	4,572
Texas	6,048	0	6,824	0	12,872	Mapel (1967); Perkins and Lonsdale (1955).	14,000	0	14,000	26,872
Utah	[11]23,541	[11]180	0	0	[11]23,721	Doelling 1970, 1971a, b, c, d, e, f, Doelling and Graham, (1970: 1971); H. H. Doelling (written commun., 1971).	[12]21,000	35,000	56,000	79,721
Virginia	9,352	0	0	335	9,687	Brown and others (1952).	5,000	100	5,100	14,787
Washington	1,867	4,190	117	5	6,179	Beikman and others (1961).	30,000	15,000	45,000	51,179
West Virginia	100,628	0	0	0	100,628	Headlee and Nolting (1940).	0	0	0	100,628
Wyoming	12,705	107,951	([2])	0	120,656	Berryhill and others (1950; 1951).	325,000	100,000	425,000	545,656
Other States	[13]610	[14]32	[15]46	0	688		1,000	0	1,000	1,688
Total	686,033	424,073	449,519	21,362	1,580,987		1,306,280	337,105	1,643,385	3,224,372

[1] Identified resources: Specific, identified mineral deposits that may or may not be evaluated as to extent and grade, and whose contained minerals may or may not be profitably recoverable with existing, technology and economic conditions.

[2] Hypothetical resources: Undiscovered mineral deposits, whether of recoverable or subeconomic grade, that are geologically predictable as existing in known district.

[3] Estimates by H. M. Beikman (Washington), H. L. Berryhill, Jr. (Wyoming), R. A. Brant (Ohio and North Dakota), W. C. Culbertson (Alabama), H. H. Doelling (Utah), K J. Englund (Kentucky and Virginia), B. R. Haley (Arkansas), E. R. Landis (Colorado and Iowa), E. T. Luther (Tennessee), R. S. Mason (Oregon), C. E Robinson (Missouri), J. A. Simon (Illinois), J. V. A. Trumbull (Oklahoma), C. E. Wier (Indiana), and the author for the remaining States.

[4] Small resources of lignite included under subbituminous coal.

[5] Small resources of anthracite in the Bering River field believed to be too badly crushed and faulted to be economically recoverable (Barnes, 1951).

[6] Includes coal in the Dakota Formation of the Black Mesa field, some of which may be of subbituminous rank. Does not include small resources of thin and impure coal in the Deer Creek and Pinedale fields.

[7] See other summary reports on coal resources in individual States as follows: Arizona (Averitt and O'Sullivan, 1969); Georgia (Butts and Gildersleeve, 1948; Sullivan, 1942); Illinois (Cady, 1952); Kansas (Abernathy and others, 1947); Missouri (Hinds, 1913; Searight, 1967); eastern Montana (Averitt, 1965); Ohio (Struble and others, 1971); Oregon (Mason and Erwin, 1955; Mason, 1969); Pennsylvania anthracite (Ashley, 1945; Ashmead, 1926; Rothrock, 1950); and Utah (Averitt, 1964).

[8] Small resources of lignite in beds generally less than 30 in. thick.

[9] From Ashley (1944).

[10] Small resources of meta-anthracite in the Narragansett basin believed to be too graphitic and too badly crushed and faulted to be economically recoverable as fuel.

[11] Excludes coal in beds less than 4 ft thick.

[12] Includes coal in beds 14 in. or more thick, of which 14,000 million tons is in beds 4 ft or more thick.

[13] California, Idaho, Nebraska, and Nevada.

[14] California and Idaho.

[15] California, Idaho, Louisiana, and Mississippi.

and the need to protect oil and gas wells and fields. From the long-term national point of view, average recoverability is probably about 50 percent. However, it is not desirable to report coal resource data on an arbitrary recoverable basis, because experience with most commodities has shown very significant long-term changes in what is regarded as economically recoverable. Coal in the ground is a more certain value that can be modified now or in the future by any recoverability factor deemed appropriate.

IDENTIFIED RESOURCES

DISTRIBUTION BY SELECTED CATEGORIES

In addition to the distribution by rank of the identified resources of 1,581 billion tons as presented in table 27, about 60 percent of this total has been classified into additional categories according to the thickness of overburden, degree of reliability of estimates, and thickness of beds as shown in figure 16. This classified tonnage is fairly large and is widely distributed in 21 States; it is likely to be reasonably representative of the total identified tonnage.

Overburden.—Figure 16 clearly shows the pronounced concentration of identified resources in the 0–1,000-foot overburden category. This concentration results in part from the fact that coal-bearing rocks are near the surface in most parts of the United States, and in part from the fact that progressively less information is available for the more deeply buried beds. Much of the tonnage classed as hypothetical in figure 17 is in the 1,000–2,000-foot and the 2,000–3,000-foot overburden categories. As exploration and development are carried to greater depth it is certain that the identified resources will be considerably increased by addition of tonnage in the deeper overburden categories.

Degree of reliability of estimates.—Figure 16 also shows the progressive increase in tonnage from the measured to the inferred categories. In the 0–1,000-foot overburden category, for example, 8 percent of the tonnage is classified as measured, 23 percent as indicated, and 58 percent as inferred. The same relation can be observed in the deeper overburden categories. The large percentage of inferred coal reflects merely distance from points of known information. Resources classified as "inferred" obviously exist, but the locations of such tonnage may differ slightly from those assumed to make the calculations. As mapping and exploration continue, the

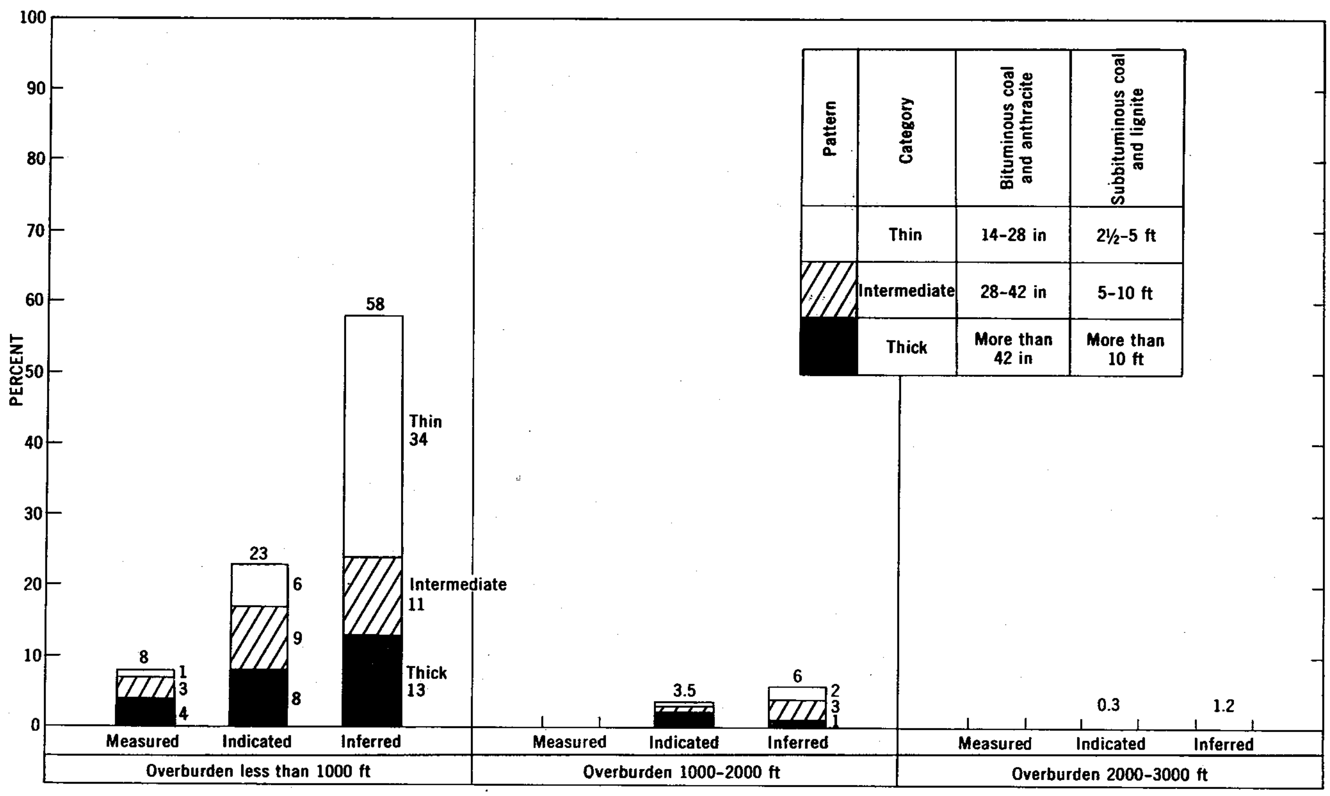

FIGURE 16.—Approximate percentage distribution of original identified U.S. coal resources by major resource categories.

percentage of coal classified as measured and indicated will surely increase.

Thickness of beds.—Coal in thick beds, 0–1,000 feet below the surface comprises 4 percent measured, 8 percent indicated, and 13 percent inferred, for a total of 25 percent of the identified resources shown in figure 16. This percentage, when applied to the total of 1,581 billion tons, is equivalent to nearly 400 billion tons. This choice tonnage is in a thickness and overburden category comparable to that of coal now being mined, and is therefore of current and near-current economic interest.

Coal in beds of intermediate thickness, 0–1,000 feet below the surface, makes up 23 percent of the identified resources, and is equivalent to 350 billion tons. This tonnage is of less immediate economic interest than tonnage in the thicker beds. However, some coal in this thickness and overburden category is currently being mined, and the total must be considered a paramarginal resource that will become of increasing economic interest and importance in the future.

Coal in thin beds, 0–1,000 feet below the surface, makes up 41 percent of the identified resources, and coal in all thickness categories, 1,000–3,000 feet below the surface, makes up the remaining 11 percent. This coal is of little current economic interest.

The amount in any category or combination of categories can be derived from figure 16 by the procedure used above.

STRIPPING COAL RESOURCES

In a recently published study, the U.S. Bureau of Mines (1971) concluded that the remaining stripping coal resources of the United States as of January 1, 1968, totaled 118 billion tons. Of this total, about 90 billion tons, or 80 percent, is within reach by present machinery and methods of mining, but only 45 billion tons is both available for use and economically recoverable.

For purpose of comparison, the larger total of 118 billion tons of stripping coal resources is 7.5 percent of the total of 1,581 billion tons of remaining identified resources as reported in table 27.

The 45 billion tons of potentially recoverable stripping coal includes 32 billion tons of low-sulfur coal (less than 1 percent), 4 billion tons of medium-sulfur coal (1–2 percent), and 9 billion tons of high-sulfur coal (more than 2 percent).

HYPOTHETICAL RESOURCES

The preceding analysis of the distribution of identified coal resources provides convincing evidence that unmapped and unexplored areas in known coal fields contain substantial additional resources that must be classed as hypothetical. The approximate magnitude of the additional hypothetical resources has been estimated by a process of extrapolation from nearby areas of identified resources, and estimates for each State are presented in separate columns in table 27. The total tonnage of hypothetical resources actually exceeds by a small amount the tonnage of identified resources. Figure 17 shows the percentage relation between identified and hypothetical resources in four overburden categories.

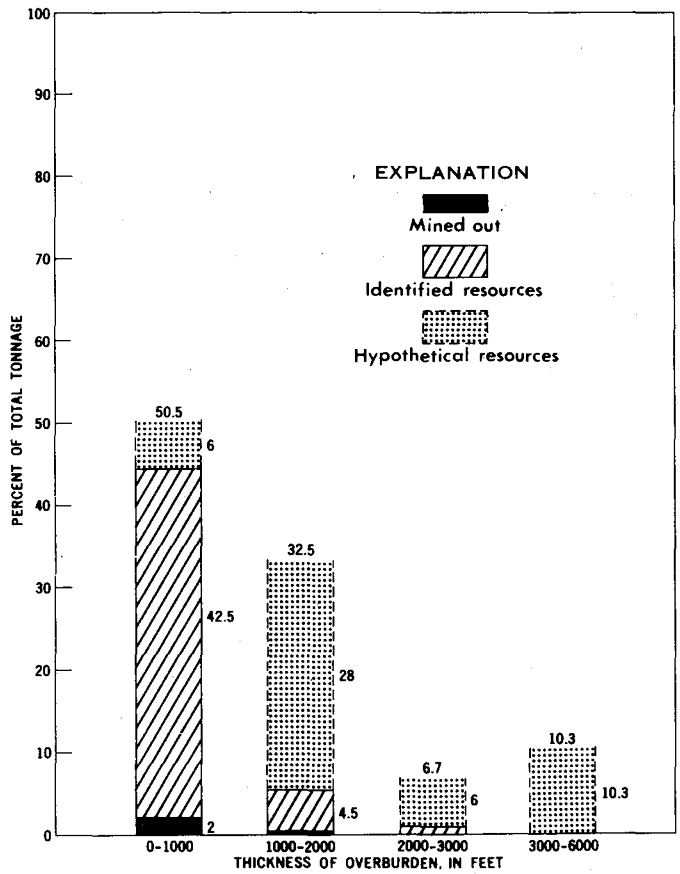

FIGURE 17.—Probable distribution of total estimated U.S. coal resources according to thickness of overburden.

Although large, the hypothetical resources are, for the most part, relatively inaccessible for mining at present, and a more exact delineation of the magnitude, distribution, and future utility of such resources will require a substantial amount of detailed geologic mapping, exploration, and study over a long period. Nevertheless, the estimated hypothetical resources constitute an important part of the total resource that needs to be considered in future planning for the utilization of all energy resources.

SPECULATIVE RESOURCES

The resources presented in table 27 and discussed under the headings of identified and hypothetical resources represent total resources within limits established by the minimum thickness of coal beds and the maximum thickness of overburden. The major geologic features of the United States are known well enough to justify the statement that, in all probability, no major coal fields remain to be discovered. Hence the coal resources of the United States are all either identified or hypothetical. Because there are no undiscovered districts, there are no speculative resources.

WORLD COAL RESOURCES

The original identified coal resources of the world total about 9,500 billion tons, the additional hypothetical resources total about 7,330 billion tons, and the two categories combined total 16,830 billion tons. The distribution of this tonnage by continents is shown in table 28.

TABLE 28.—*Estimated total original coal resources of the world, by continents* [1]

[In billions of short tons]

Continent	Identified resources [2]	Hypothetical resources [3]	Estimated total resources
Asia [4]	[5] 7,000	4,000	[6] 11,000
North America	1,720	2,880	4,600
Europe	620	210	830
Africa	80	160	240
Oceania	60	70	130
South and Central America	20	10	30
Total	[5] 9,500	7,330	[6] 16,830

[1] Original resources in the ground in beds 12 in. or more thick and generally less than 4,000 ft below the surface, but includes small amounts between 4,000 and 6,000 ft.
[2] Identified resources: Specific, identified mineral deposits that may or may not be evaluated as to extent and grade, and whose contained minerals may or may not be profitably recoverable with existing technology and economic conditions.
[3] Hypothetical resources: Undiscovered mineral deposits, whether of recoverable or subeconomic grade, that are geologically predictable as existing in known districts.
[4] Includes European U.S.S.R
[5] Includes about 6,500 billion short tons in the U.S.S.R.
[6] Includes about 9,500 billion short tons in the U.S.S.R. (Hodgkins, 1961, p. 6).

The figures for the United States as shown in table 27 are included in the total for North America in table 28. On the basis of identified resources, the United States contains about one-sixth of world resources; on the basis of total resources, the United States contains about one-fifth of world resources.

Table 28 shows clearly that Asia contains most of the world's total coal resources. This tonnage is concentrated in the U.S.S.R. and China, both of which are important coal-producing countries. The table also shows that the coal resources of Europe have been well established by mapping and exploration, and that estimates will not be greatly increased by future work. Finally, table 28 shows that Africa, Oceania, and South America contain small resources as compared with the rest of the world, but that the quantities assumed to be present are sufficient to justify continued exploration and development. (See Averitt, 1969, p. 81–85.)

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