THE IOWA BITUMINOUS COAL INDUSTRY

by

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INTRODUCTION

General Statement

Coal is one of the five primary energy sources in major use by man, the other four being water power, petroleum, nuclear energy, and wood. Of these only coal and petroleum (including both oil and natural gas), classed as fossil fuels, are in current widespread use in the United States. It is interesting to note that water power, used to generate electricity, has never accounted for more than a few percent of the nation's total energy requirements. Of the other two forms, wood went out of use long ago, and the utilization of nuclear energy for direct heating or for steam generation of electricity has not yet become widespread. Problems in the construction of suitable reactors for this purpose set the delivery of power reactors well behind projected schedules. It will take perhaps ten years of actual operation until the economics of nuclear power production will be known well enough to allow confident expansion by potential users. These facts lead to the conclusion that nuclear energy will not be fully competitive with the fossil fuels for perhaps the next two decades.[1]

Variation of the proportion of the nation's total energy requirement supplied by coal reflects the industrial growth and development of the nation. In the year 1850 over 90% of the fuel used in the United States was wood; at that time coal contributed less than the remaining 10%. Seventy years later coal supplied 78% of our energy needs, the remainder being supplied by petroleum products (18%) and water power (slightly less than 4%). By 1940 the corresponding figures for coal and petroleum were 52% and

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[1]Reference No. 55, page 46.

44%; by 1965 coal had declined to 23% and petroleum had increased to 73%, occupying roughly the same relative position as that held by coal only 45 years earlier.[2]

The national shift from coal to petroleum products was reflected in the continuous decline of coal production in the State of Iowa. As far as the state's economy was concerned, this loss of revenue was further intensified by a multiplier effect due to the fact that energy was supplied from sources (petroleum) produced outside of Iowa. Production of coal increased in Iowa from 1840 through 1917, with a maximum annual production of 9,049,806 short tons from 246 mines. The industry declined continuously thereafter to a production of 878,366 short tons from 14 mines in 1968.

Regardless of the shift away from coal, production of coal is still important in the economies of the state and the nation. Coal remains in many cases the least expensive primary fuel for steam generation, resulting in lower electric bills to consumers and lower heating bills for tenants of large buildings. Coal is used for the manufacture of coke, an indispensable ingredient in the production of the basic heavy construction material of our time, steel. Coal with adequate coking properties has not been located in economic quantities in Iowa. However, Iowa coal is well suited for use in modern steam generation plants.

Why then has the Iowa bituminous coal industry declined almost to the vanishing point while coal industries of other states and the nation have expanded, or at very least remained essentially stable? This is a simple question requiring a complex answer which is dependent upon wide knowledge

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[2]Reference No. 26, pages 24 and 66.

Table 1. Production statistics of the Iowa bituminous coal industry, 1945-1968[a]

Year	Number of mines	Number of employees	Production, short tons
1945	168	2955	2,071,648
1946	152	2642	1,741,140
1947	158	2227	1,687,590
1948	165	2209	1,666,774
1949	148	2046	1,749,861
1950	158	1713	1,931,022
1951	128	1478	1,600,143
1952	99	1123	1,410,259
1953	88	940	1,354,587
1954	78	794	1,097,651
1955	81	768	1,266,678
1956	67	664	1,310,489
1957	70	660	1,277,002
1958	67	548	1,178,388
1959	63	526	1,176,047
1960	51	511	1,057,125
1961	48	462	930,491
1962	40	418	1,133,586
1963	35	407	1,211,614
1964	39	359	971,977
1965	31	271	1,045,607
1966	25	249	1,025,765
1967	18	175	896,556
1968	14	---	878,366

[a]Reference No. 43, page 17-18.

of both the economics and technology involved in the mining and marketing of Iowa coal. Much of the knowledge necessary for a complete answer of this question, and of several related questions of equal importance regarding the industry, has not been made available to the public. In some instances pertinent knowledge may not exist at all. The purpose of this study is to compile all available information on the economics and technology of the modern Iowa coal industry in a single reference.

Although numerous studies directly or indirectly concerned with the industry have appeared since 1840, all but a few of these are highly technical and of narrow scope. With the exception of a half-dozen technical studies completed after 1945, those currently available are of little or no value to the person interested in describing and understanding today's industry. They were outdated due to sweeping post-World War II changes in the economic conditions prevailing in Iowa and the rest of the Midwest coal market area, and to similar changes in the technology of the industry. In order to eliminate this lack of information an integrated study of the social, economic, and technological status of the industry is needed. This thesis is intended as the first step in such a study.

The attainment of these objectives requires investigation of many of the variables involved in the industry. The variables investigated include technology, the recent economic statistics, political history, legal history, and labor history of the industry, and the geology of Iowa coal. These are discussed separately, but it cannot be over-emphasized that they are all intricately interrelated. The bulk of the study deals with:

1. The geology of the coal deposits (including the events which occurred during their formation and which controlled the occurrence and

properties of the coal);

2. The technology of coal mining as applied to the Iowa deposits;

3. The costs of producing the coal using current mining methods;

4. The costs of selling the product and of transporting it to the purchaser;

5. The analysis of competition between coal producers and between producers of coal and the producers of alternative fuels.

Each of these variables was studied as thoroughly as possible in the available time (nine months). The results of this study are for the most part general, and it is hoped that each of the variables will be studied in detail in the future.

Several major industry problems, each of them contributing to the decline of the industry, were recognized during the course of this investigation. Although these problems are discussed in detail later on, they are presented here to lend perspective to further reading:

1. With the exception of the past decade, most of the Iowa coal producers have been quite slow to modernize their plants, mining methods, and business practices.

2. A problem presented by the small size of most of the individual mines is related to the economies of scale (reduction of cost per unit of output with increased volume of production). These have effectively restrained the industry from benefits attainable through large scale production.

3. Certain inequities appear to exist in the structure of rail transportation freight rates applied to Iowa coal. This coupled with the preceding two problems eliminates the borrowing power of the producers as a

consequence of their inability to produce more than marginal business profits. Borrowed funds are necessary in the financing of capital improvements and expansion. Above all other factors, the freight rate structure has resulted in actual reduction of the market for Iowa coal.

4. Lack of sound geologic information about the coal deposits makes location of economically mineable deposits and the selection of the most efficient methods of mining nearly impossible.

In the hope that this thesis will be of use to those persons interested in the Iowa bituminous coal industry, an attempt has been made to present the results in such a manner as to appeal to a variety of backgrounds and interests. Wherever possible, technical terminology has been eliminated. When this was impossible, the term is either defined in the text or its definition was placed in a glossary to be located in the Appendices. Use of the main subheadings of the index will guide the reader with limited time to those topics in which he is most interested, although all readers would probably benefit by reading the sections on the recent history of the industry and the discussion section.

Acknowledgements

Before proceeding with the main text, the author wishes to express his appreciation to his graduate committee: Dr. John Lemish, Chairman, Dr. Karl E. Seifert, Dr. Lyle V. A. Sendlein, and Dr. Robert W. Thomas of the Iowa State University of Science and Technology for the provision of valuable direction, encouragement, and constructive criticism.

Additionally, without the exceptional degree of cooperation of the following persons and their organizations, this study would have been infeasible, and to them the author extends his sincere appreciation for their efforts:

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Mr. W. Dean Aubrey	Iowa State Mine Inspector
Mr. Jack Mich	Owner, Mich Coal Company
Mr. Thomas Wignall	General Manager, Lovilia Coal Company
Mr. Raymond Antonette	Rate Division, Iowa Commerce Commission
Dr. H. Garland Hershey	Former State Geologist of Iowa

HISTORY OF THE INDUSTRY

Recent Statistical History

The early history of the Iowa coal industry is not important to the understanding of it as it is currently operated.[3] The period of interest is from the end of World War II to the present. The position of the Iowa industry is best understood by comparison with the national industry, as sweeping changes occurred in both with respect to modernization of mining techniques and alteration of prevailing economic conditions during this time period. The effects of the changes are reflected in industry statistics, which are presented here in the form of simple graphs plotted by computer from Federal and State government data describing the production level, employment, and number of mines operating in each year. The computer technique used yields two results: a plot of the various data points, indicating actual year-to-year variation, and a statistically-fitted smooth curve through the points, which accurately represents the trend in the industry during the period. The plots are presented and discussed in pairs, the first plot being that of the national industry, and the second the corresponding plot for the state industry.

Production level

Production levels are presented in Figures 1 and 2. While both plots show wide variation about the trend line from year to year, the overall

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[3]Readers interested in the early history of the Iowa bituminous coal industry are referred to an excellent account, Coal Mining in Iowa, by Dr. Hubert L. Olin, published by the Iowa Department of Mines and Minerals, Des Moines, Iowa (Reference No. 33).

Figure 1. United States bituminous coal output, 1945-1966. Data from Reference Nos. 56-77 inclusive

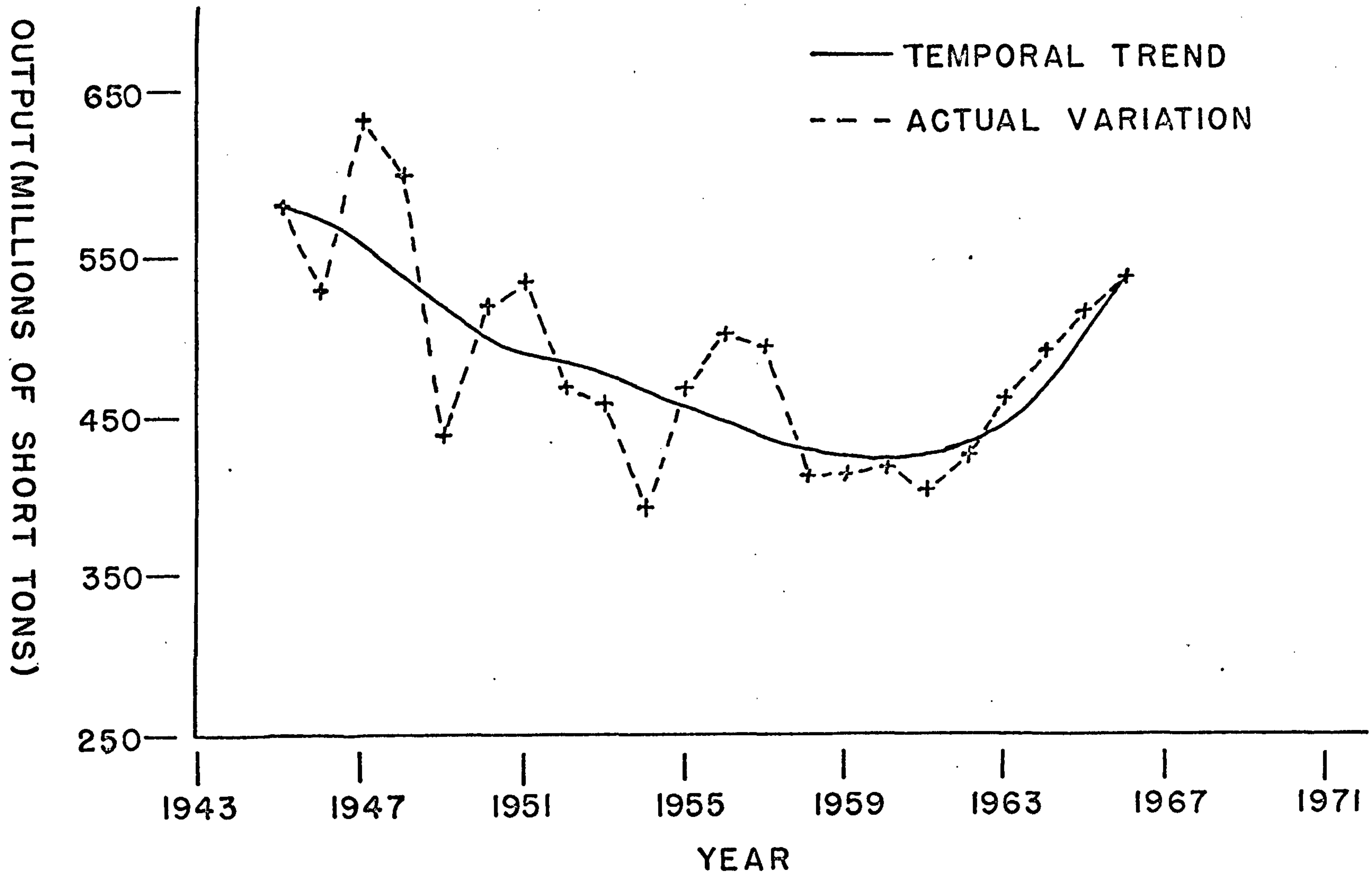
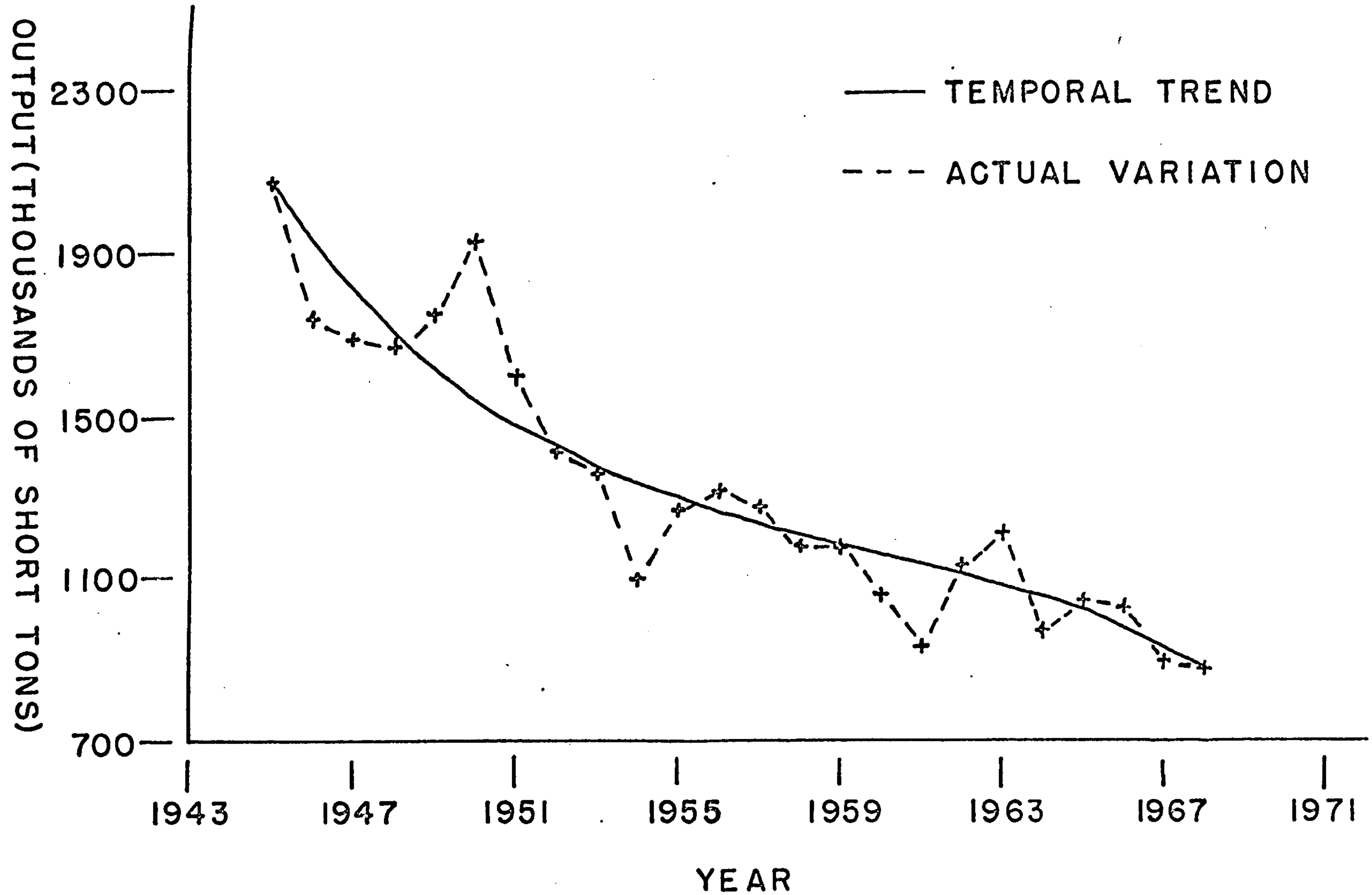

TEMPORAL TREND
ACTUAL VARIATION
OUTPUT (MILLIONS OF SHORT TONS)
650
550
450
350
250
1943
1947
1951
1955
1959
1963
1967
1971
YEAR

Figure 2. Iowa bituminous coal output, 1945-1968. Data from Reference Nos. 39-51 inclusive


TEMPORAL TREND
ACTUAL VARIATION
OUTPUT(THOUSANDS OF SHORT TONS)
2300
1900
1500
1100
700
1943
1947
1951
1955
1959
1963
1967
1971
YEAR

trends are consistent. National production declined at approximately the same rate as did state production from 1945 until 1960. At that time, the national trend began recovering, achieved its postwar level in 1966, and surpassed it in the succeeding two years. The Iowa industry continued its decline in production at least through 1968. Production in 1969 thus far appears to be higher than that of 1968, although final figures are not yet available.

Number of mines in operation

Accompanying the decline in production from Iowa mines was a drastic reduction in the number of mines operating. Nationally, the number of operating mines has fluctuated wildly since 1945, between limits of 10,000 and 6,000 mines. The Iowa and national curves for this variable are not consistent (see Figures 3 and 4). The number of operating mines in Iowa changed from 168 in 1945 to 14 in 1968.

Employment

Figures 5 and 6 indicate the employment trends in the state and national industries respectively. Employment dropped rapidly in both during the postwar period. Employment in Iowa changed from 2,955 in 1945 to 175 in 1967.

Trend analysis

As of 1968 the Iowa industry was producing at less than half its postwar level. The decline in production during this period was directly caused by a severe reduction in the market for Iowa coal. The reduction was in turn caused by a combination of unfortunate factors:

Figure 3. Number of bituminous coal mines operating in the United States, 1945-1966. Data from Reference Nos. 56-77 inclusive

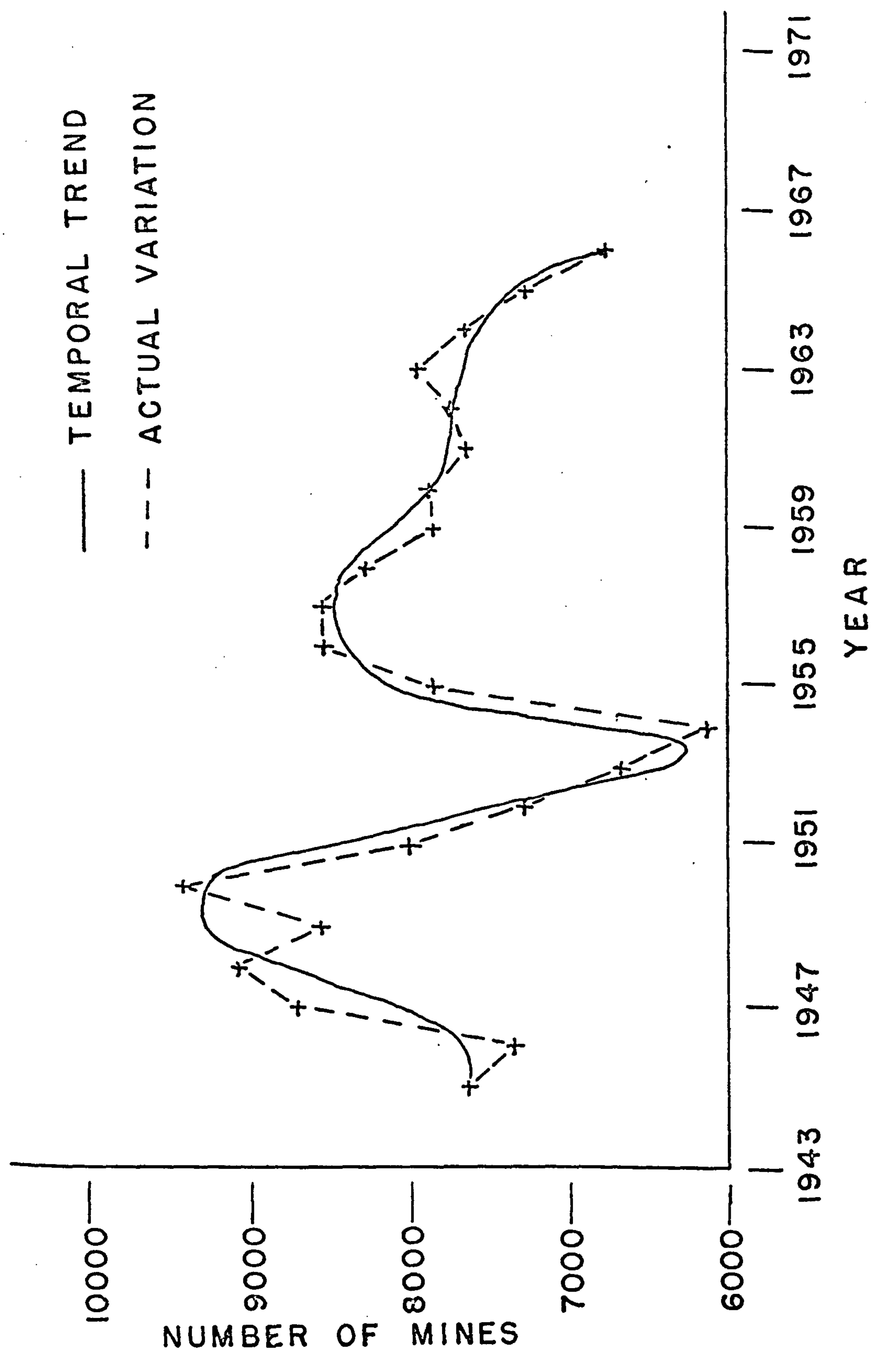

TEMPORAL TREND
ACTUAL VARIATION
NUMBER OF MINES
10000
9000
8000
7000
6000
YEAR
1943
1947
1951
1955
1959
1963
1967
1971

Figure 4. Number of bituminous coal mines operating in Iowa, 1945-1968. Data from Reference Nos. 39-51 inclusive

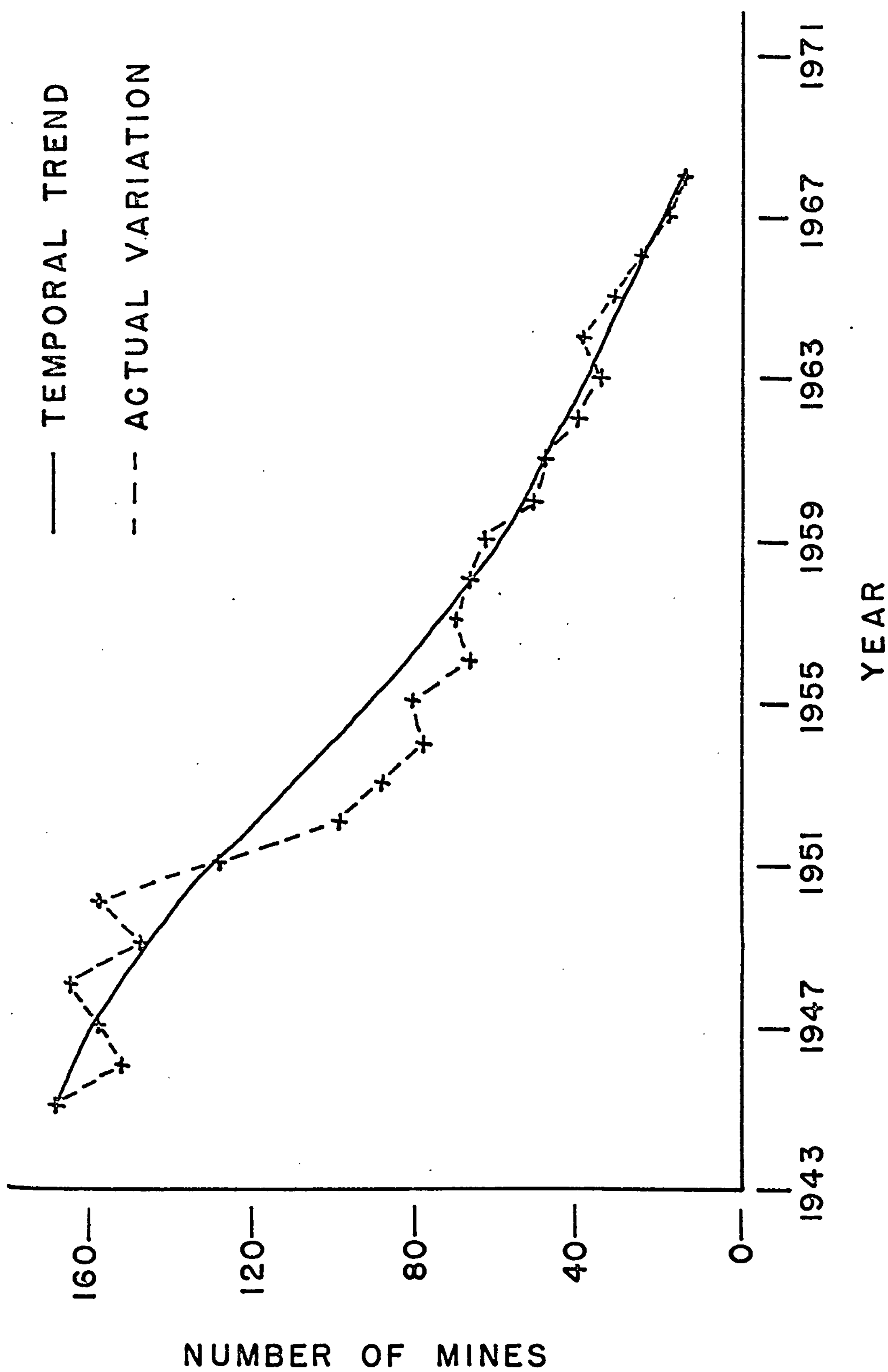

TEMPORAL TREND
ACTUAL VARIATION
NUMBER OF MINES
160
120
80
40
0
1943
1947
1951
1955
1959
1963
1967
1971
YEAR

Figure 5. Employment in United States bituminous coal mines, 1945-1966. Data from Reference Nos. 56-77 inclusive

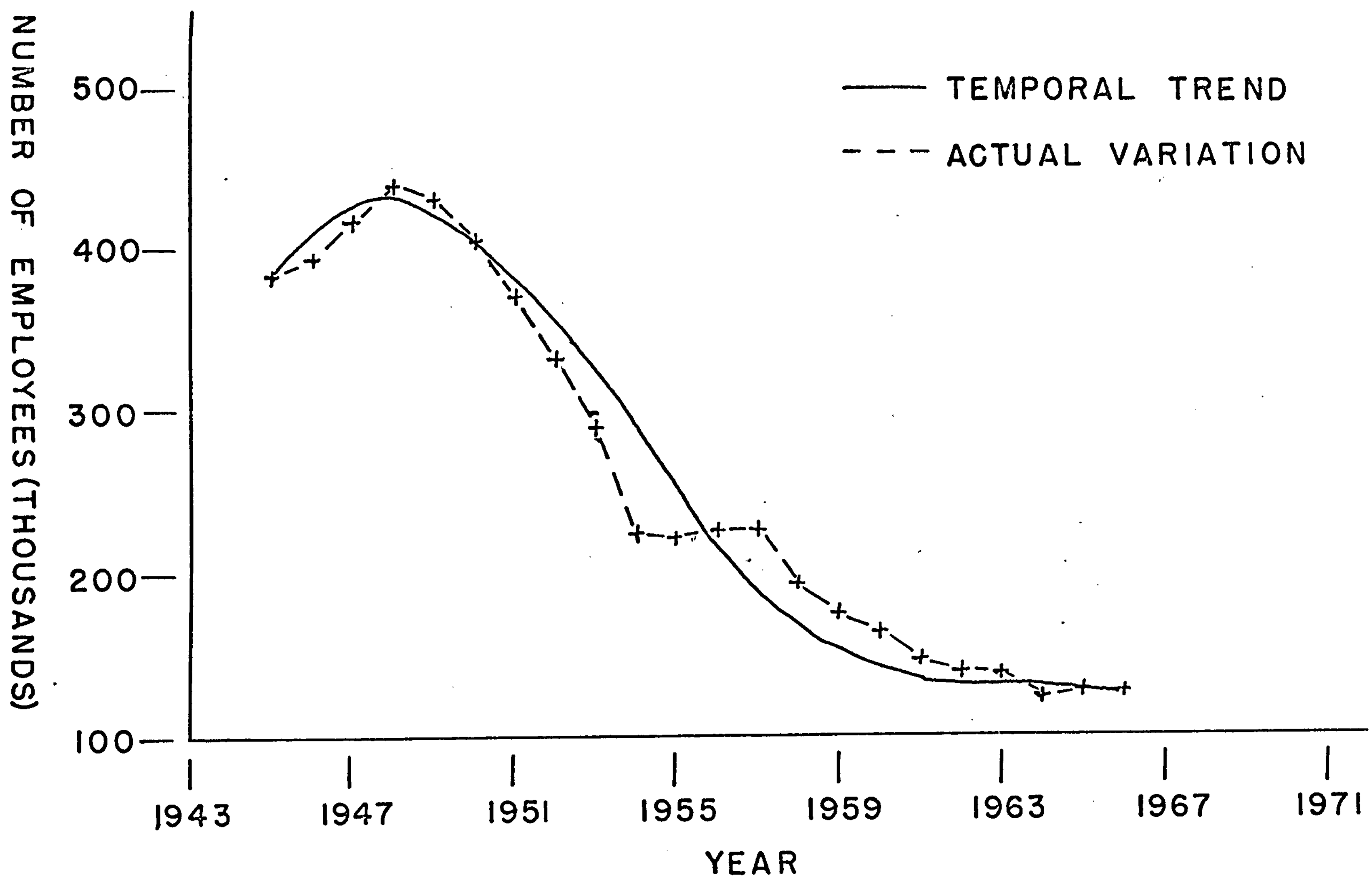
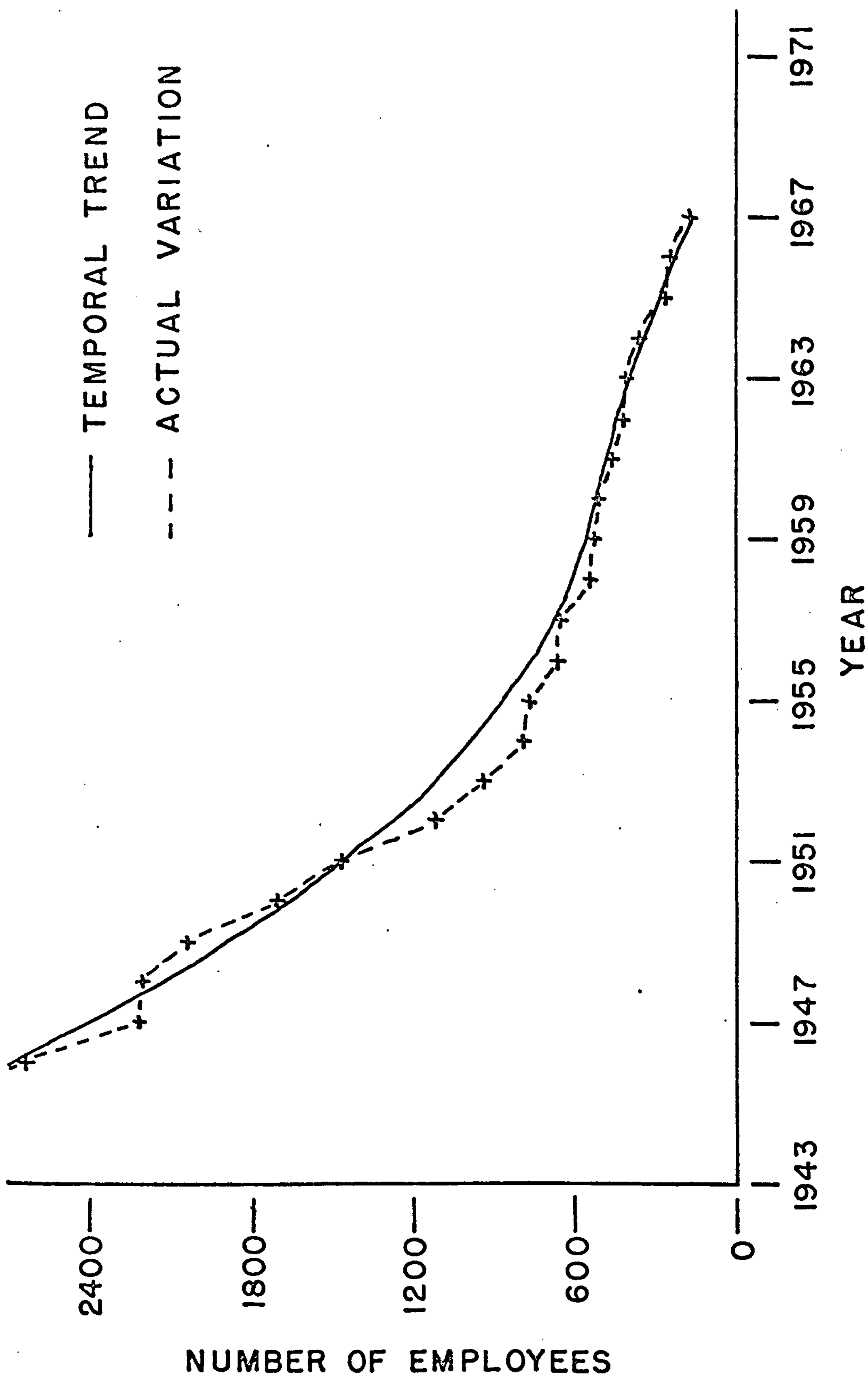

TEMPORAL TREND
ACTUAL VARIATION
NUMBER OF EMPLOYEES (THOUSANDS)
500
400
300
200
100
1943
1947
1951
1955
1959
1963
1967
1971
YEAR

Figure 6. Employment in Iowa bituminous coal mines, 1945-1968. Data from Reference Nos. 39-51 inclusive


TEMPORAL TREND
ACTUAL VARIATION
YEAR
1943
1947
1951
1955
1959
1963
1967
1971
0
600
1200
1800
2400
NUMBER OF EMPLOYEES

1. Abolition of restricted wartime market areas.

2. Evolution of unfavorable transportation procedures, including the availability of bulk transport and freight rate structures suitable to coal haulage.

3. Slowness on the part of Iowa producers to modernize, consolidate, and expand their operations.

4. Loss of the home heating and steam engine fuel markets.

Discussion of factors 2 and 3 (above) is deferred to later sections of the thesis. The first factor was important in terms of effect shortly after the war, and has declined in importance in recent years. During the war, restricted sales areas were imposed by the government, preventing competition among coal producers. Also during the war, the bituminous coal producers working fields in Indiana and Illinois greatly increased their production capacities by modernizing their production methods and drastically increasing the size of their mines, while Iowa mines remained small and for the most part technologically inferior. When the war ended and the sales restrictions were abolished, the Illinois producers in particular had an easy time capturing the coal markets serviced by Iowa producers, with the sole exception of those coal users located in central and western Iowa, to which the Illinois mines could not ship economically.

During the war great advances in the production, distribution, and utilization of petroleum products were made. After the war the technology thus developed was applied to the heating of homes and to the replacement of the steam-powered railroad engine with diesel engines, eliminating almost entirely two of the significant prewar markets for Iowa coal. Iowa coal was used during the early postwar period much in the same capacity as it is currently used, for large-scale space heating and the generation of steam for production of electricity.

The reduction of the number of operating mines reflects both the reduced demand for coal and the slowness of operators to modernize. The Iowa mines operating in 1945 were small, mostly hand operated by a very few personnel (the average was 17 men per mine), and unable to compete with the larger out-of-state mechanized producers over much of the Midwest. Nearly all of these mines were forced out of business. The remaining mines are those which have successfully increased their size and modernized their production techniques. Figure 7 indicates the rate and magnitude of the increase in output per operating mine during the postwar period. The remaining mines have favorable locations with respect to their current markets in terms of transportation availability and costs. The reduction in number of operating mines in the state may be viewed essentially as a healthy, although painful, trimming of marginal and sub-marginal operations.

The reduction in employment in Iowa mines reflects both the reduction of the number of operating mines and the shift from hand-mining techniques to mechanized, modern operations. This shift increased the productive capacity of each worker considerably. Figure 8 is a plot of annual output per man for the national industry, and Figure 9 is a similar plot for the Iowa industry. Both show increased output per man through time, with the Iowa statistics showing a greater rate of increase. In 1967, Iowa operations produced at an average level of 21.13 short tons per man per day, as opposed to a national average of about 18.5 short tons per man per day.

Figure 7. Average annual output per mine, Iowa bituminous coal mines, 1945-1968. Data from Reference Nos. 39-51 inclusive

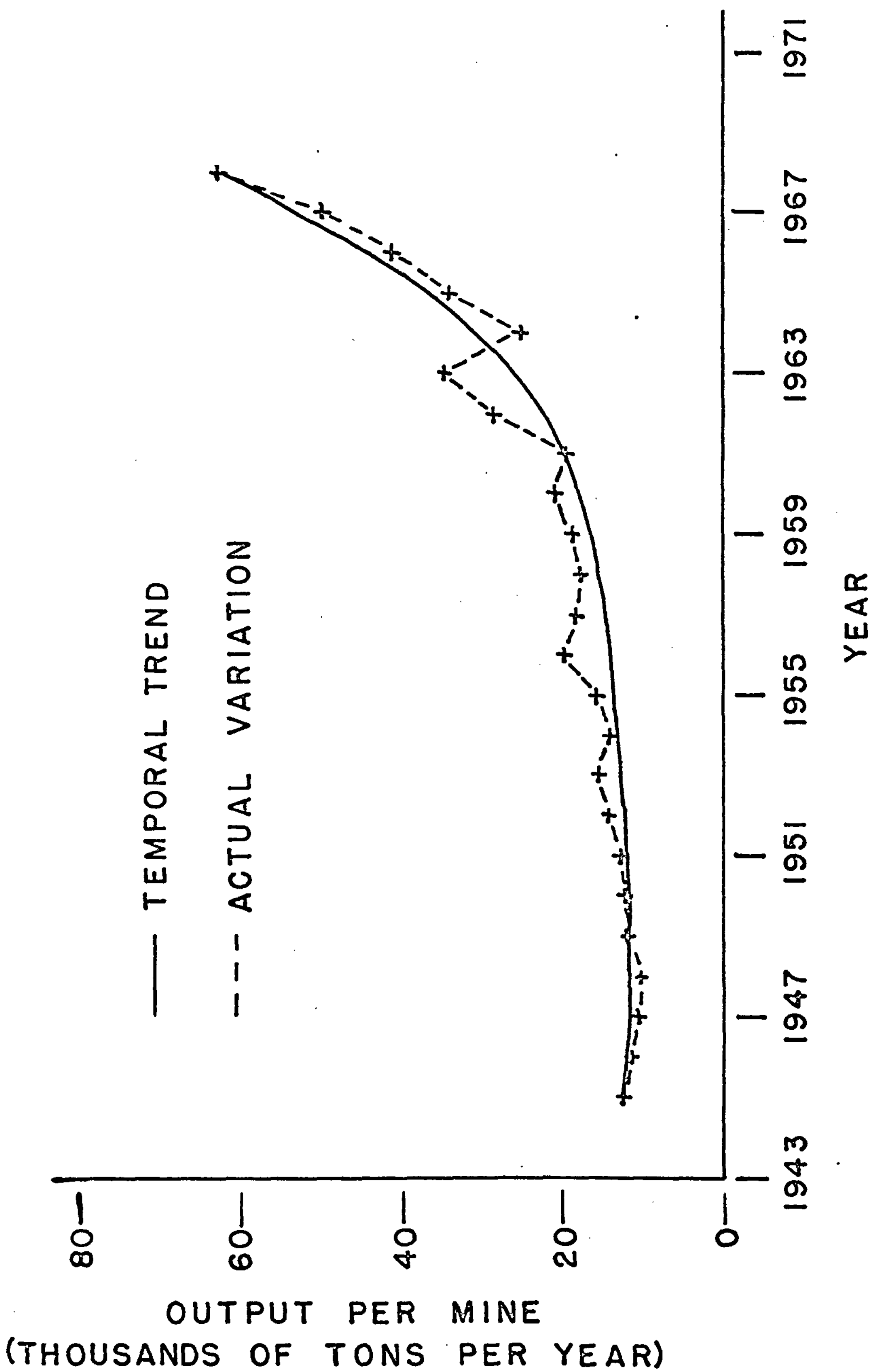

TEMPORAL TREND
ACTUAL VARIATION
OUTPUT PER MINE
(THOUSANDS OF TONS PER YEAR)
0
20
40
60
80
1943
1947
1951
1955
1959
1963
1967
1971
YEAR

Figure 8. Average annual output per employee, Iowa bituminous coal mines, 1945-1968. Data from Reference Nos. 39-51 inclusive

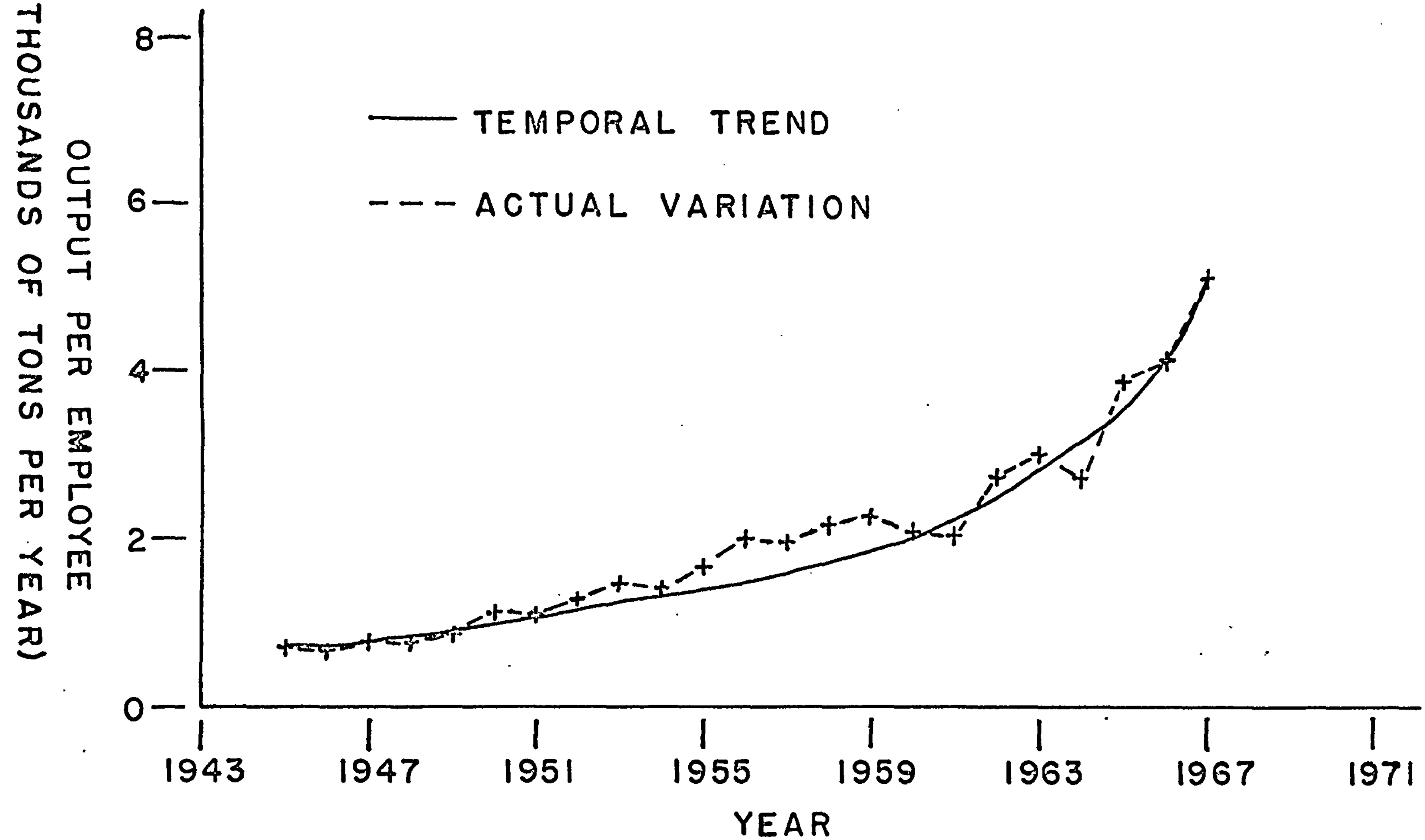
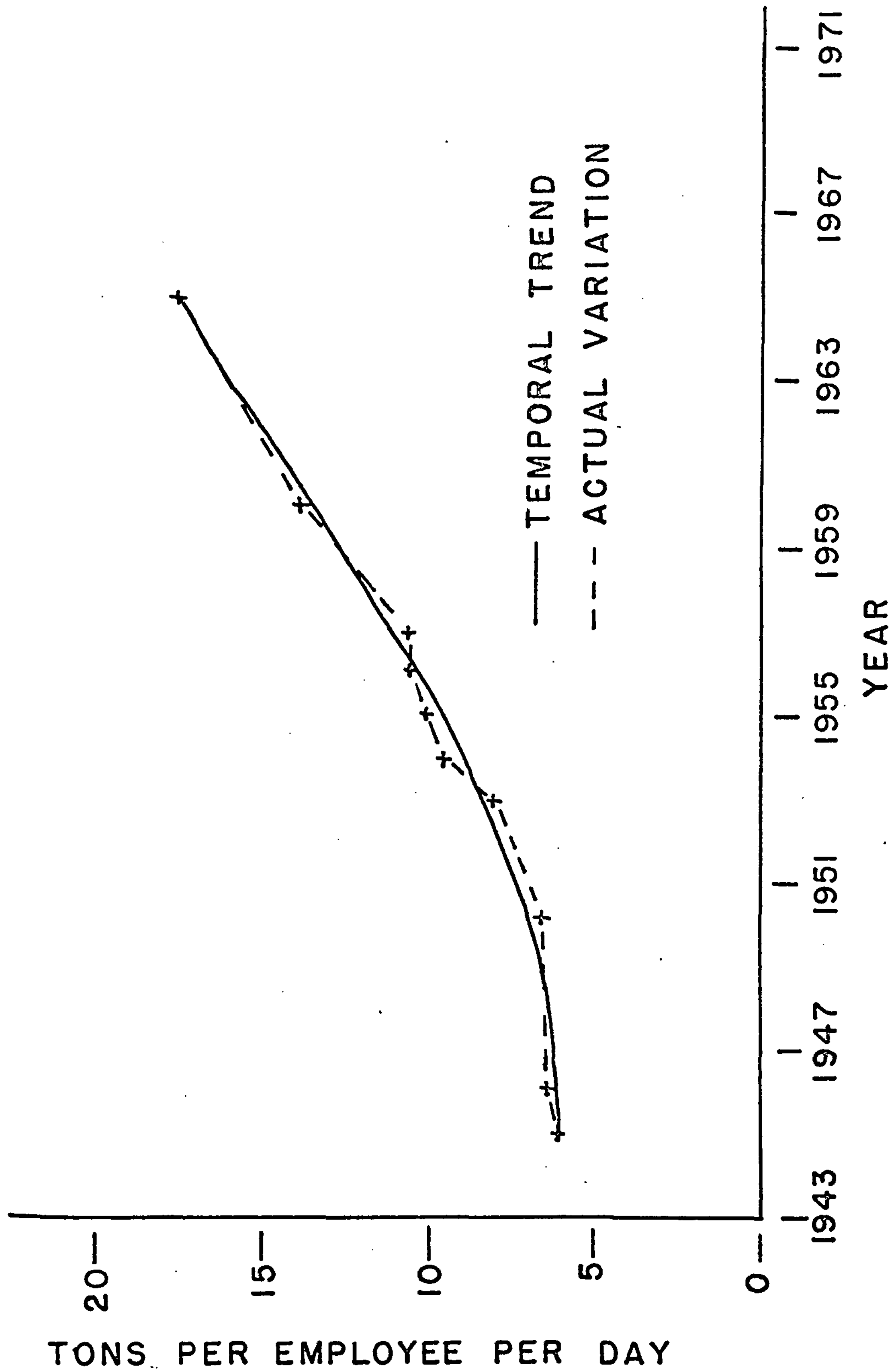

OUTPUT PER EMPLOYEE
(THOUSANDS OF TONS PER YEAR)
8
6
4
2
0
TEMPORAL TREND
ACTUAL VARIATION
1943
1947
1951
1955
1959
1963
1967
1971
YEAR

Figure 9. Average tons produced per man per day, United States bituminous coal mines, 1945-1966. Data from Reference Nos. 56-77 inclusive



TEMPORAL TREND
ACTUAL VARIATION
TONS PER EMPLOYEE PER DAY
0
5
10
15
20
YEAR
1943
1947
1951
1955
1959
1963
1967
1971

Labor Relations

Based upon mine inspections made by the author during the course of this investigation, workers currently operating the mines are reasonably satisfied with their working conditions and are utilized by management in a highly efficient manner. The state has a colorful history of labor disputes which occurred during the late-Nineteenth and early-Twentieth Centuries. Several of these resulted in riots requiring control by the Iowa National Guard. This situation is, of course, far in the past.

Most of the mines currently operating are family owned, and labor requirements not fulfilled by family members are fulfilled by local non-union labor hired either on a share or contract basis. This is possible due to the small size of the individual operations, with the number of employees per operation ranging from three or four up to about twenty.

Legal History

The Iowa statutes regulate mining with respect to mine safety and, since January 1, 1968, with respect to rehabilitation of land disrupted by surface mining. The mining law is enforced by a five-member State Mining Board through the Office of the State Mine Inspector, State Department of Mines and Minerals. The statutes covering mine safety are fairly standard and modern, regulating the manner in which mines shall be operated, and requiring appropriate examinations for licensing of supervisory and hoisting personnel.

The law concerned with land rehabilitation requires the licensing of mine operators (at a current annual fee of fifty dollars) accompanied by posting of a current minimum bond of one-hundred dollars for each acre of land to be mined by stripping or other surface-disruptive methods. Both the license and the bonds are forfeitable upon failure to comply with the land rehabilitation statutes. Important excerpts of these statutes are presented in the Appendices. Along with enactment of the statutes, the legislature wisely appropriated funds to the State Mining Board for the development of a demonstration strip mine rehabilitation project. This has successfully been completed at the Hull Mine Area, about 5 miles west of Oskaloosa on the south side of Highway 92.[4]

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[4]Reference No. 38.

THE GEOLOGY OF IOWA COAL

This chapter is devoted to a brief overview of the geology of Iowa coal deposits and the effects it has on the mining operations and on the subsequent use of the coal. Modern, detailed studies of the general geology of Iowa coal deposits and their associated rocks are not available. Most studies completed prior to 1945 consist of detailed qualitative descriptions of single deposits or of closely related deposits.[5] These contain an inadequate quantity of material concerned with broad inter-relationships. Conversely, the few studies completed after 1945 are much wider in scope, but limited in depth.[6] Detailed, comprehensive study of the Pennsylvanian System rocks of Iowa should be undertaken to remedy these deficiencies.

Background Information

The rocks most commonly associated with coal deposits are classified as sedimentary rocks. These rocks are often composed of small, weathered grains of pre-existing igneous, metamorphic, or sedimentary rocks. The grains were in most cases transported as sediment to a new location, redeposited, and lithified (compacted and cemented), thus forming a new rock body of the sedimentary type. Alternatively, sedimentary rocks may be composed of fragments of the non-organic parts of once-living organisms, as in some carbonate rocks, or of altered plant material, as in coal.

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[5] Reference Nos. 52 and 53 (pages 609-657).

[6] Reference Nos. 24 and 27.

The most distinctive characteristic of sedimentary rocks is perhaps the presence of layering within the rock bodies. This characteristic is readily observed in most Iowa quarries and along many of the major streams of the state. Each layer is called a stratum. A stratum may vary greatly in thickness and surface (areal) extent, but has about the same lithology throughout, i.e., it consists of approximately the same type of sedimentary rock throughout (limestone, dolomite, sandstone, shale, coal, or other sedimentary rock type). A stratum represents essentially continuous deposition of the same type of sediment, and the plane between strata represent periods of non-deposition of varying duration. As one stratum is deposited atop the previous stratum a vertical sequence of sedimentary strata forms. Excluding the pre-Cambrian rocks, the full sequence of sedimentary strata found in Iowa is approximately 6800 feet thick, as graphically illustrated in Figure 10, the Stratigraphic Column of Iowa. Note that all of the strata are not present at any one location. About 5000 feet of sedimentary strata have been penetrated by wells in the deeper parts of the Iowa section of the Forest City Basin.[7] The Iowa column represents literally millions of strata. By means of various dating techniques these have been assigned relative ages with respect to each other and with respect to the present. The full thickness of strata represented by the column required some 600 million years to form.

Consideration of each stratum individually would be, to say the least, unwieldly. Geologists have therefore adopted certain conventions which

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[7]Reference No. 82, page 18.

Figure 10. The Stratigraphic Column of Iowa

STRATIGRAPHIC COLUMN OF IOWA

SYSTEM	SERIES	GROUP	FORMATION	DESCRIPTION	THICKNESS	(MILLION YEARS)
QUAT-ERNARY	Pleistocene		Wisconsin	loess, glacial till and interbedded sand and gravel	500'	
			Illinoian			
			Kansan			
			Nebraskan			1
CRET-ACEOUS		Colorado	Carlisle	shale	350'	
			Greenhorn	limestone and shale		
			Graneros	shale		
		Dakota		sandstone and shale	200'	
		?	Fort Dodge beds	gypsum, red and green shales in Webster County only	50'	90
PENNSYLVANIAN	Virgil	Wabaunsee	French Creek	shale	210'	
			Jim Creek	limestone		
			Friedrich	shale		
			Grandhaven	limestone		
			Dry	shale		
			Dover	limestone		
			Langdon includes (Nyman Coal)	shale		
			Maple Hill	limestone		
			Wamego	shale		
			Tarkio	limestone		
			Willard	shale		
			Elmont	limestone		
			Harveyville	shale		
			Reading	limestone		
			Auburn	shale		
			Wakarusa	limestone		
			Soldier Creek	shale		
			Burlingame	limestone		
			Silver Lake	shale		
			Rulo	limestone		
			Cedar Vale (includes Elmo bed at top)	shale		
			Happy Hollow	limestone		
			White Cloud	shale		
			Howard	limestone		
			Severy (includes Nodaway coal bed at base)	shale		
		Shawnee	Topeka	limestone	180'	
			Calhoun	shale		
			Deer Creek	limestone		
			Tecumseh	shale		
			Lecompton	limestone		
			Kanwaka	shale		
			Oread	limestone		
		Douglas	Lawrence	shale	110'	
			Stranger	shale		
	Missouri	Pedee	Iatan	limestone		
			Weston	shale		
		Lansing	Stanton	limestone	50'	
			Vilas	shale		
			Plattsburg	limestone		
		Kansas City	Bonner Springs	shale	215'	
			Wyandotte	limestone and shale		
			Lane	shale		
			Iola	limestone and shale		
			Chanute	shale		
			Drum	limestone		
			Quivira	shale		
			Westerville	limestone		
			Cherryvale	shale		
			Dennis	limestone and shale		
			Galesburg	shale		

PENNSYLVANIAN			Swope	limestone		
			Ladore	shale		
			Hertha	limestone		
		Pleasanton	undifferentiated	shale and sandstone, thin coal beds	40'	
	Des Moines	Marmaton	Lenapah	limestone	145'	
			Nowata	shale		
			Altamont	limestone and shale		
			Bandera	shale		
			Pawnee	limestone and shale		
			Labette	shale		
			Fort Scott	limestone		
		Cherokee	undifferentiated	shale, sandstone, thin limestones and coal	755'	310
MISSISSIPPIAN	Meramec		Ste. Genevieve	shale and limestone	140'	
			St. Louis	sandy limestone		
			Spergen	limestone		
	Osage		Warsaw	shale and dolomite	250'	
			Keokuk	cherty dolomite and limestone		
			Burlington	cherty dolomite and limestone		
	Kinderhook and undifferentiated		Gilmore City	limestone, oolitic	820'	
			Hampton	limestone and dolomite		
			McCraney	limestone		
			English River	siltstone		
			Maple Mill	shale		
			Aplington	dolomite		
			Sheffield	shale		345
DEVONIAN	Upper		Lime Creek	dolomite and shale	225'	
			Shell Rock	limestone and dolomite		
	Middle		Cedar Valley	limestone and dolomite	270'	
			Wapsipinicon	limestone and dolomites, shales in middle		390
SILURIAN	Niagaran		Gower	dolomite	300'	
			Hopkinton			
	Alexandrian		Kankakee	cherty dolomite	100'	
			Edgewood	sandy dolomite		425
ORDOVICIAN	Cincinnatian		Maquoketa	dolomite and shale	300'	
	Mohawkian		Galena	dolomite and chert	320'	
			Decorah	limestone and shale		
			Platteville	limestone, shale and sandstone	70'	
	Chazyan		St. Peter	sandstone	50'-230'	
	Beekmantown		Prairie du Chien	sandy and cherty dolomite and sandstone	290'	500
CAMBRIAN	St. Croixan	Trempealeau	Madison[a]	sandstone	185'	
			Jordan			
			Lodi[a]			
			St. Lawrence	dolomite		
			Franconia	glauconitic sandstone, siltstone, shale	160'	
		Dresbach	Galesville	sandstone	550'	
			Eau Claire	sandstone and shale, dolomite		
			Mt. Simon	sandstone		600?
PRECAMBRIAN				sediments (sandstones), igneous, and metamorphic rocks		

[a] recognized only in extreme northeast Iowa

Iowa Geological Survey
1962

Figure 10. (Continued)

enable grouping of sequences of strata which have easily recognizable characteristics and distinct boundaries into larger, more easily managed units. The basic unit is the formation, which is the smallest unit appearing in the Iowa column. The formations are further organized into increasingly larger units: groups, series, and systems. All of the rock units discussed in the following sections are referred to by their system, series, group, and formation names.

Origin of the Coal Deposits

The origin of the coal deposits must be considered not only in terms of the physical conditions necessary to coal development, but also in terms of the geologic history of the deposits. The applicable history begins before the formation of the first coal deposits and ends at the present time. It is convenient to separate this time interval into three divisions, the first beginning before deposition of the sediments which make up the rocks of the Pennsylvanian system (pre-Pennsylvanian), the second beginning with the deposition of the sediments which make up the rocks of the Pennsylvanian system, and the third following the end of Pennsylvanian deposition (post-Pennsylvanian).

The pre-Pennsylvanian interval

At some time prior to the deposition of the Pennsylvanian system sediments a topographically and structurally depressed area known as the Forest City Basin began to develop. The basin may be visualized as a large, extremely shallow marine bay, the axis of which ran from its shallower northeastern end to its somewhat deeper southwestern end. Most of the basin lay in what are now Kansas, Nebraska, and Missouri.[8] A smaller portion occupied parts of southern and southwestern Iowa (see Figure 11). Its shoreline was irregular, with many small embayments, inlets, and shallow lagoons. The basin persisted at least during the time period within which the late-Mississippian and Pennsylvanian sediments were deposited.

During the Chesterian interval at the end of the Mississippian the Iowa portion of the basin floor was uplifted to a position above sea level. At this time the nearest point of marine sedimentation was in southern Missouri.[9] The Iowa climate during Chesterian time was probably warm and humid, perhaps like that of today's Florida climate, allowing rapid erosion of the exposed Mississippian limestone rocks. A hilly topography with well-developed stream drainage was soon formed.[10] This Mississippian erosion surface was then partially resubmerged as the basin floor receded beneath sea level. Those portions of the basin not submerged exhibited numerous youthful stream channels running directly into the ocean. Swamps thick with plant growth began to develop in the lowlands along the streams and at their mouths.

The Pennsylvanian period

The deposition of Pennsylvanian sediments began in Iowa about 310 million years ago and continued for about 30 million years (see Figure 10).

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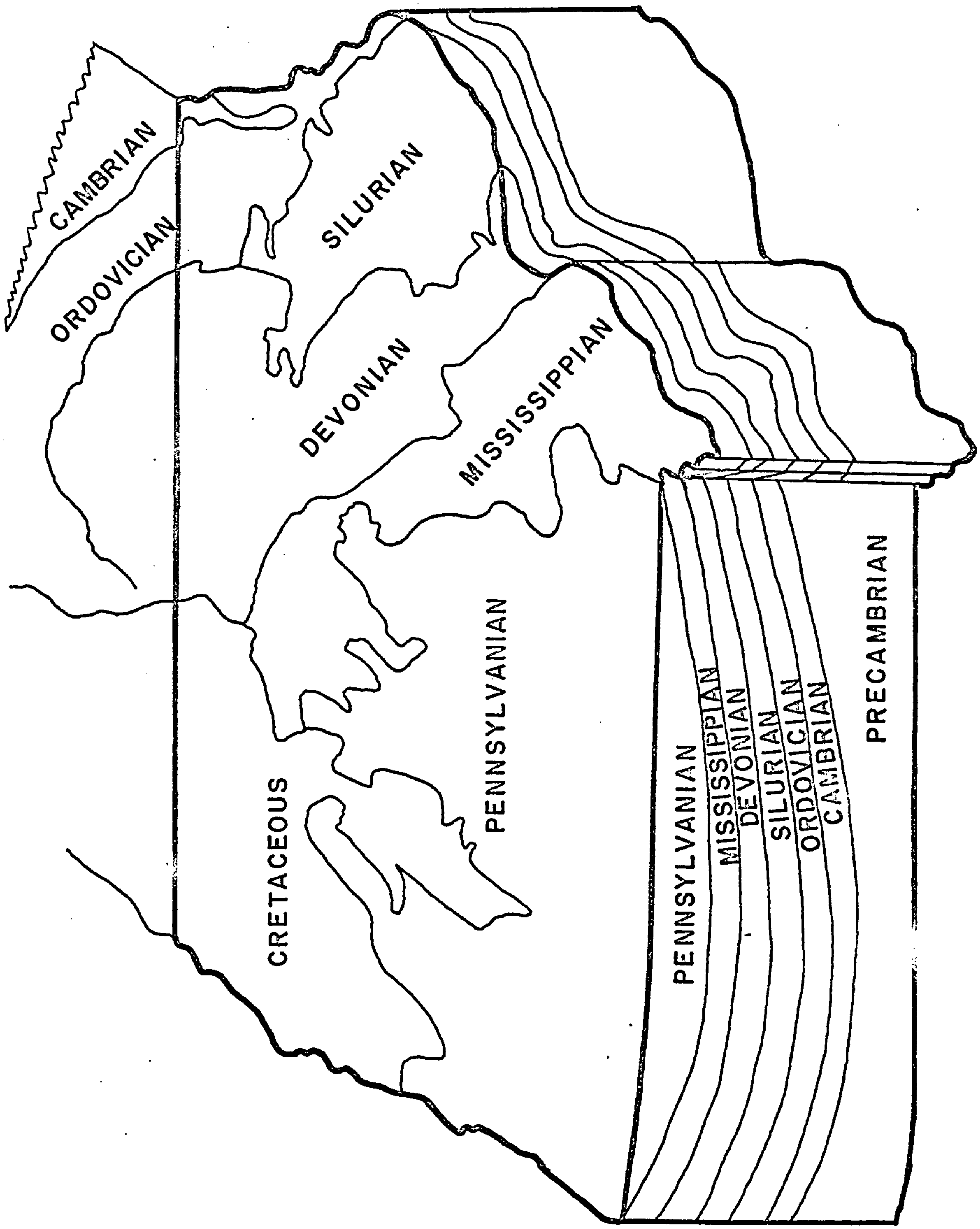
[8]Reference No. 24, page 35; Reference No. 25, page 10.

[9]Reference No. 19, page 435.

[10]Reference No. 28, page 14.

Figure 11. Generalized surface and subsurface geology of Iowa. After Lemish, Reference No. 28. Area labelled Pennsylvanian roughly coincides with the position of the Forest City Basin


CAMBRIAN
ORDOVICIAN
SILURIAN
DEVONIAN
MISSISSIPPIAN
PENNSYLVANIAN
CRETACEOUS
PENNSYLVANIAN
MISSISSIPPIAN
DEVONIAN
SILURIAN
ORDOVICIAN
CAMBRIAN
PRECAMBRIAN

During this time the shoreline of the Forest City Basin continuously shifted back and forth across Iowa in response to vertical adjustments of the land mass with respect to sea level. These adjustments were similar to those which occurred near the end of the Mississippian period, but apparently most were of smaller magnitude. The swamps may have shifted their positions laterally when possible, remaining near the shoreline, or new swamps may have formed after each adjustment. The succession of inundations of the land mass by the sea resulted in cyclic deposition of marine and non-marine sediments at the margins of the basin.

Complete sequences of sedimentary strata formed as a result of one complete cycle (from marine to non-marine and back to marine conditions) are called cyclothems.[11] An ideal cyclothem, as it would be encountered during drilling from the surface, is as follows (the individual lithologic units, or rock types, contained in the cyclothem are numbered in the order of their deposition):[12]

12.	Shale (and coal in some instances)	Non-marine
11 -5.	Alternating shale and limestone	Marine
4.	Coal	
3.	Underclay	Non-marine
2.	Shale	
1.	Sandstone	

Ideal cyclothemic sequences of units do not occur in the Forest City Basin. This is not surprising as the ideal sequence was first described

[11]Reference No. 79, page 1003.

[12]Reference No. 31, page 24-25.

in the Illinois Basin, which had its own unique set of environmental conditions. The deposits in the Forest City Basin, and particularly those of the Iowa portion of the basin, differ in their lithologic sequences from deposit to deposit, indicating that environmental and physical conditions which controlled the properties of the deposits also varied. No systematic, detailed studies of these sequence differences or of the variations in conditions which caused them have been attempted in Iowa. Preliminary study is reported by Hershey, *et al*.[13] A composite (average or typical) section of an Iowa cyclothem is as follows:[14]

6.	Sandstone *or* limestone	
5.	Shale with ironstone nodules or ironstone sheets at base	Marine (?)
4.	Coal	
3.	Possible clay parting and/or thin shale with overlying fireclay	
2.	Coal	Non-marine
1b.	Sandstone or limestone (Des Moines series deposits)	
or 1a.	Shale from higher series deposits	

Comparison clearly demonstrates the discrepancy between this sequence and the sequence of the ideal cyclothem. R. C. Moore attempted to classify the Shawnee group of the Virgil series rocks of Kansas into what he chose to call megacyclothems in an attempt to bypass this difficulty, but similar classification does not appear to work well in Iowa.[15] Much careful stratigraphic study is needed before the Iowa cyclothems will be well understood.

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[13]Reference No. 24.

[14]Average column of Iowa cyclothem based on descriptions in Reference No. 25.

[15]Reference No. 31.

In addition to the lack of detailed descriptions of the cyclothemic sequences present within the Pennsylvanian rocks of Iowa, no concerted attempt has been made to fully identify (correlate) those deposits which are of the same age as those in adjacent states, with the notable exception of the Mystic Coal seam in the Marmaton group of the Des Moines series.[16] Several good studies have been done in other states located in the Basin.[17] Most of the stratigraphic material may be found in the bulletins and reports of investigations of the Missouri, Nebraska, and Kansas geological surveys.

Up to 12 separate coal horizons have been exposed in drill holes penetrating the Pennsylvanian rocks of southern Iowa. Four of these horizons are known to contain coal deposits of commercial value. Current knowledge of the deposits is based on data obtained from a low areal density of drill holes and an even lower density of exposures in coal mines. While it is inferred from this data that the "typical" Iowa coal deposit was formed in a small swamp isolated from nearby swamps, the possibility exists that this conclusion is premature and based on insufficient data.

Factors affecting the size of Iowa coal deposits

The number of coal horizons and their uniformly distributed stratigraphic positions within the Pennsylvanian rocks of Iowa indicate that climatic conditions favorable to swamp growth and peat burial were prevalent throughout Pennsylvanian time. Other factors must therefore account for the apparent discontinuity of known commercial coal deposits, since the coal

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[16]Reference No. 27, page 33-34.

[17]Reference No. 20, Reference No. 30.

horizons are identifiable over areas much larger than any of the known coal deposits. Figure 12 shows the coal horizons.

Without doubt the principal factor limiting thickness of the coal seams was differential compaction and shrinkage accompanying transformation of the peat into coal. Local thickness variations could easily have been caused by differences in the thickness and density of overlying sedimentary material, resulting in differences in the lithostatic pressure to which the peat was subjected.[18]

When considering factors limiting the areal extent of the coal deposits it is necessary to distinguish between deposits formed within the confines of valley walls of pre-swamp streams and those formed in the less constrained deltaic and on-shore marine environments located along the margin of the Forest City Basin. The areal extent of stream channel deposits must have been controlled by the slope of the land surface; given profuse plant growth throughout the area only the nearly flat areas would allow peat accumulation. Deposits formed in the stream channels should therefore have an elongate, probably sinuous plan trending along the bottom of the valley, a pronounced lensatic cross-section, and should terminate against the pre-swamp valley fill at their base and the pre-swamp valley wall-rocks at their margins.

Since the deltaic and near-shore environments are very flat-lying to begin with, factors other than land slope must account for discontinuity. Variation in the energy of the environment along the basin margins could account for discontinuity. Peat accumulation requires the prevalence of

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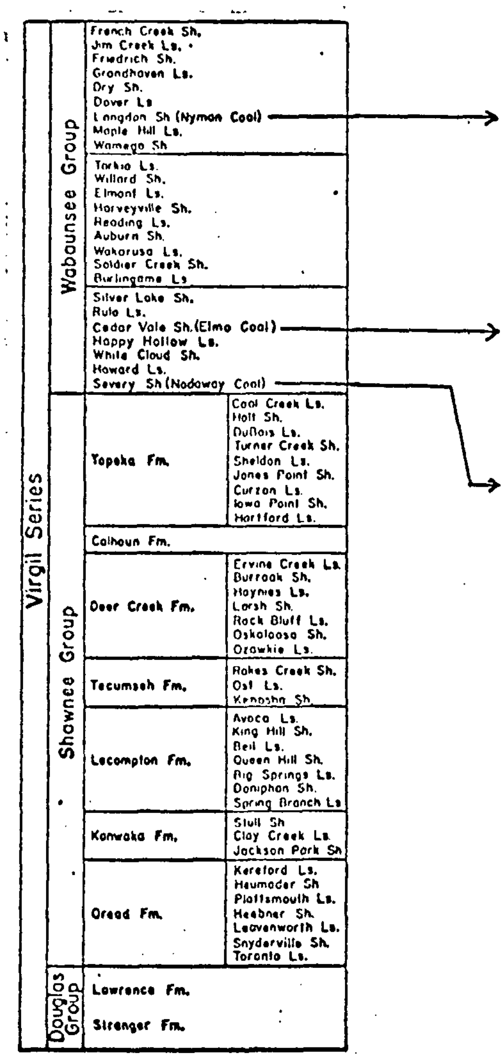
[18] Reference No. 36, pages 265-266.

Figure 12. The Pennsylvanian Stratigraphy of Iowa. After Landis, Reference No. 27



Nyman. Very lenticular. 14 inches thick or less.

Elmo. Very lenticular. 14 inches thick or less.

Nodaway. Persistent. Three feet or less in thickness. Averages 14-18 inches thick.

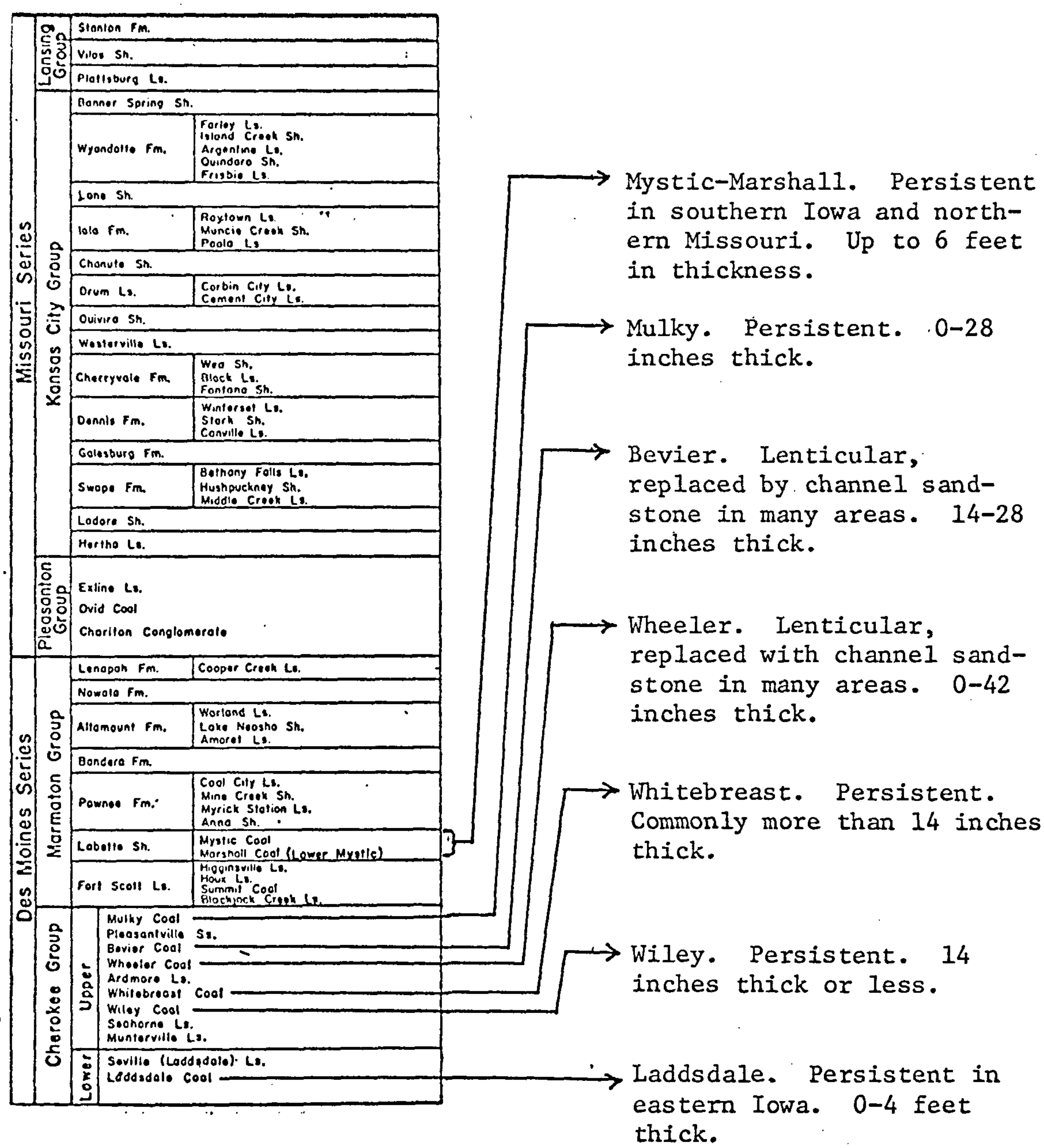


Figure 12. (Continued)

calm, slow water circulation (or preferably no circulation at all) in the swamps, i.e., a low energy environment. Such conditions would not exist offshore of places where active streams entered the Pennsylvanian sea, forming a locally higher energy environment. Since low gradient deltas of the type probably present in the Pennsylvanian usually exhibit a complex, braided stream pattern, many deposits of peat in the deltaic areas would be discontinuous in nature, separated by narrow braided stream channels. The deltaic deposits would be expected to have irregular plans and should grade laterally into sandstone and siltstone channel fills. Deposits formed in areas between points of stream inflow might be expected to grade seaward into black shales whose fine sediments were carried out past the immediate deltas of the streams, and laterally into rocks composed of sediment particles larger than those of the black shales. The near-shore deposits should have elongate plans trending along the shoreline with lateral interruptions opposite points of stream inflow. Their cross-sections (at approximate right angles to the shoreline) should be lensatic, although less pronounced than in the stream channel deposits. Such environments should produce coal deposits of greater lateral continuity than those of the other environments, and would therefore produce deposits of greater economic value.

It should be emphasized that these are by no means all the possible reasons for coal deposit discontinuity and that they are at this time largely conjectural, as adequate data for testing these hypotheses are lacking. At present the apparent discontinuity of the deposits makes correlation difficult, as most of the larger commercial coal deposits are only a few hundred acres or so in area. Considerable effort will have to be directed toward study of the geology of the deposits to acquire the data needed for accurate interpretation. The outcome of such interpretation has important consequences for the future of the Iowa coal industry, a topic which will be returned to in the discussion section.

The genesis of coal

The first requirement for coal genesis is prolific growth of plant material. Since approximately 20 feet of plant material are required to produce one foot of coal,[19] it has been estimated that the mineable Iowa coal beds, which range in thickness from 2 1/2 to 6 feet, required about 7500 to 18000 years of uninterrupted plant growth, depending on coal thickness.

The second requirement is that the plant growth take place under swamp conditions. The dead vegetation must be submerged beneath the water surface of the swamp in an oxygen-free (reducing) environment shortly after death of the plants, as it would otherwise decay. Submergence allows only partial decay into the form of peat.

The third requirement is that the floor of the swamp sink at exactly the same rate as plant material is added to it. If no floor subsidence occurred, assuming no change in the water level, the swamp would soon fill up with peat and the water would disappear. Conversely, if the floor subsided too rapidly, the water would become too deep to support plant growth.

The fourth requirement is that the peat layer which has formed be buried under sediments. This occurs when the rate of subsidence becomes greater than the rate of peat formation. The burial of the peat preserves

[19]Reference No. 21, page 326.

it from destruction by erosion and oxidation and provides the static load which in turn produces the pressure necessary to convert the peat, through the process of coalification, into coal. The coalification process results in an increase in the fixed carbon content of the peat as it loses carbon dioxide, carbon monoxide, methane, hydrogen sulfide, water, and other gases. The peat first changes into a soft, brownish material called lignite, and finally to harder, black bituminous coal.[20]

Coal quality

The quality of the coal formed as a result of the above processes depends on the extent and intensity of the physical conditions attending their operation. The heating value of the coal (normally measured in British Thermal Units (B.T.U.) per pound) depends upon the carbon, nitrogen, oxygen and hydrogen concentrations in the coal. These elements are derived from the plant material which grew in the swamp. Thus the heating value is largely a function of the type of plant material converted into coal and of the degree of conversion.

The ash content of the coal represents most of the non-hydrocarbon portion, and results from washing of terrestrial mud into the swamp during plant growth. Characteristics of the ash (residue left after burning) such as the temperature at which the ash will begin to fuse, the extent to which the soft ash will form clinkers (the agglomerating index) and a measure of the degree to which the coal will coke (the free-swelling index) are determined by the composition of the mud.

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[20]Reference No. 33, pages 6-8.

Sulfur, universally present under the reducing conditions of the swamps, often combines with iron to form iron sulfides, represented in coal deposits by the minerals pyrite and marcasite. Some sulfur occurs organically in the coal. During burning these produce noxious, acid, sulfur-containing gases. These are undesirable, as they contribute to equipment breakdown through corrosion and to air pollution. The sulfide content of coal deposits is highly variable, depending on the original swamp conditions. Coals with low ash and sulfide content are especially valued by users.

Other characteristics which are dependent upon the type of plant material and on the coalification process include various physical properties of the coal such as the extent of fracturing and the hardness. These determine in turn the ease with which the coal can be broken during blasting, the ease with which it can be ground in preparation mills, and the size to which it will preferentially break (along natural fracture and joint lines).

Average analysis of Iowa coals

Careful analyses of Iowa coals are conducted on a continuing basis by the United States Bureau of Mines. A summary of these analyses is given in the Appendices. The average properties of Iowa coal are listed in Table 2.

It should be noted that individual deposits may depart widely from these average figures. For examples, some Iowa deposits have only 2-3% sulfur content, while others contain as much as 10%; BTU content may vary from about 5,000 to about 14,000 per pound.

Table 2. Average Iowa coal analysis[a]

Characteristic	Value of variable
Rank	High-volatile bituminous C
Moisture (as received)	14.2%
Volatile matter	36.3%
Fixed carbon	35.9%
Ash content	14.0%
Sulfur content	5.0%
BTU per pound (as received)	9883
BTU per pound, dry	13602
Ash-softening temperature	2022°F.
Agglomerating index	Fair-caking
Free-swelling index	3.0
Hardgrove grindability index	62

[a]Based on unweighted averaging of 295 analyses of coal from 73 mines located in 17 Iowa counties, as published in References Nos. 1-18 inclusive and No. 35.

"Contemporaneous" physical alteration of deposits

Due to the oscillation of the Pennsylvanian sea across Iowa, some of the coal deposits formed early in the Pennsylvanian were brought above sea level shortly after their formation. These were then subject to erosion; in some cases it is apparent that entire deposits were removed. More often only partial removal occurred, and stream channels formed at this time were later filled with Pennsylvanian and post-Pennsylvanian sediments upon resubmergence. In the past, mines have flooded after accidentally drifting into such filled erosion channels, as the sandstone fill is very porous and allows rapid water flow. Such flooding no longer is a problem, as the positions of channel sandstone bodies are known well in advance of mining operations from the extensive test drilling of the deposits.

The post-Pennsylvanian period

The coal deposits were physically modified during post-Pennsylvanian time. Prominent erosion occurred some time after the coal deposit formation, which ceased in Iowa about 280 million years ago. The first period of erosion occurred at and prior to the Pleistocene glaciation, which began between 1.2 million and 3 million years ago and ended less than 10,000 years ago. The second period of erosion began after glaciation ended and continues to the present. Erosion during these intervals was similar in effect to the contemporaneous erosion described earlier. Many of the early mines in the Des Moines River valley were drifted horizontally into valley fill deposits which subcropped along the buried valley walls. Cross-sectional views of deposits eroded before and after glaciation are given in Figure 13.

Summary of Iowa Coal Reserves

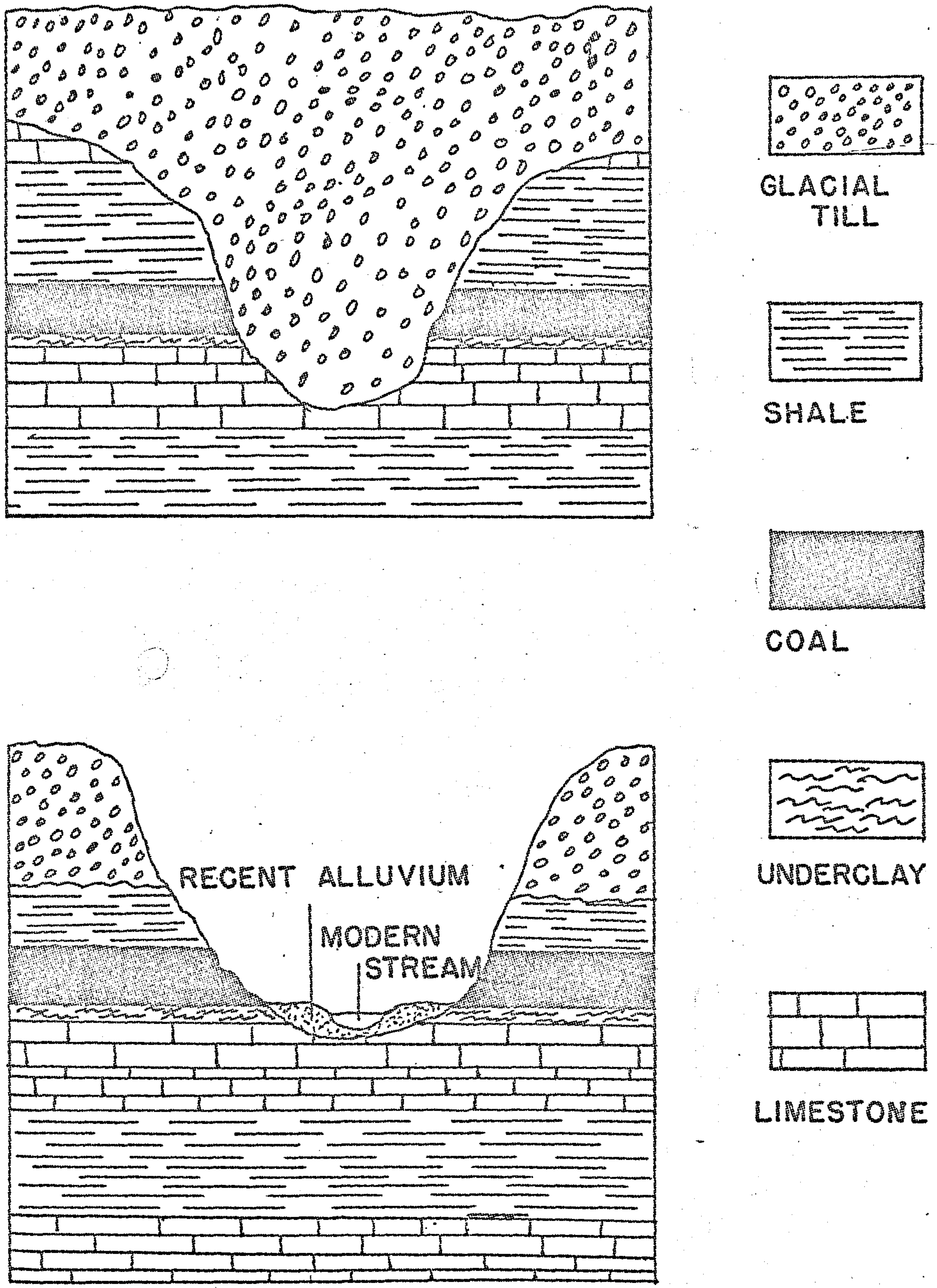
Coal-bearing rocks of the Pennsylvanian system occur at or beneath the surface of and cover approximately 36% of the State of Iowa. They are concentrated for the most part in central, south-central, and south-western Iowa.[21] Since 1840, coal has been commercially produced from more than 32 of Iowa's 99 counties. The major coal producing regions of the state are

[21]Reference No. 23, page 345.

A. Eroded before glaciation

B. Eroded after glaciation

Figure 13. Cross-sectional views of eroded deposits (after Hinds, Reference No. 25)


RECENT ALLUVIUM
MODERN STREAM
GLACIAL TILL
SHALE
COAL
UNDERCLAY
LIMESTONE

outlined in Figure 14, which also presents the total production from 1880 to 1968.

The coal deposits range from very thin (and non-commercial) bands of coal to six feet or more thick. Current commercial production is from beds more than three feet thick, as mechanical loading and mining methods are not efficiently applicable to thinner seams. The average seam thickness mined in Iowa in 1965 was 4.5 feet.[22] The commercial seams thus fall into the intermediate or thick classifications as defined by the United States Geological Survey. Individual commercial coal deposits are commonly described in terms of both their thickness and area, e.g. 20 acres of 4-foot coal. The known commercial Iowa deposits are small, at the most a few hundred acres in area.

Two different estimates of the total coal reserves of the state are available, one compiled by the United States Geological Survey (U.S.G.S.) and the other compiled by the United States Bureau of Mines (U.S.B.M.). Both estimates are presented in Table 3.

The discrepancy between the estimates is readily explained by the dates on which the estimates were first made. The U.S.G.S. estimate was published in 1965, based on work done in 1964, whereas the U.S.B.M. estimate (published in the same year) is a holdover from its origin in 1909. As considerable information about the coal horizons of the state has become available since the latter date, it would appear that the U.S.B.M. estimate is far too large.

The U.S.G.S. estimate, while excellent with respect to the data

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[22] Reference No. 26, page 6.

1	Adair	4,340	59	Lucas	13,757,861
2	Adams	694,243	62	Mahaska	40,492,763
4	Appanoose	46,248,179	63	Marion	38,395,641
8	Boone	18,882,017	68	Monroe	64,000,329
15	Cass	120	73	Page	695,928
25	Dallas	14,044,026	77	Polk	50,965,427
26	Davis	795,604	82	Scott	207,014
37	Greene	1,699,934	85	Story	30,270
39	Guthrie	485,011	87	Taylor	507,869
40	Hamilton	10,523	89	Van Buren	1,512,176
42	Hardin	8,740	90	Wapello	14,717,908
44	Henry	480	91	Warren	2,462,970
50	Jasper	10,202,389	93	Wayne	2,672,803
51	Jefferson	250,080	94	Webster	4,929,085
54	Keokuk	8,453,946		Other counties and small mines	13,018,468
56	Lee	500			

Figure 14. Current coal producing regions of Iowa. Figure after Given, Reference No. 23. Numerical data is total coal production (in short tons) within each county from 1880-1968 inclusive. Data from Reference Nos. 27, 49, 50, and 51

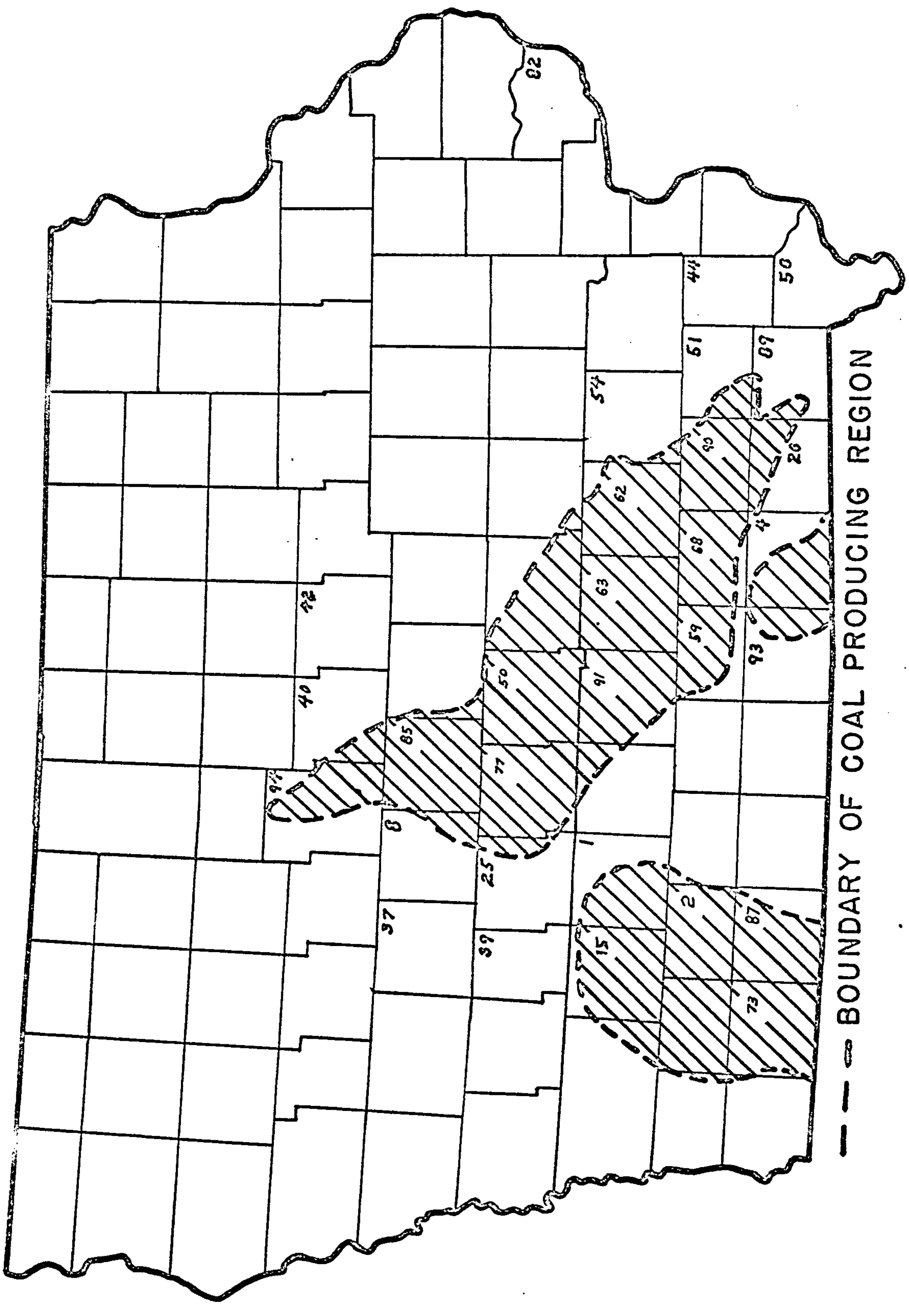
BOUNDARY OF COAL PRODUCING REGION

Table 3. Estimates of Iowa coal reserves

Estimate type	U.S.G.S.[a]	U.S.B.M.[b]
Total original reserves	7,263.54	29,160
Measured and indicated reserves[c]	1,846.17	-
Previously mined[d]	712.56	714
Remaining reserves	6,524.00	28,446
Recoverable remaining reserves[c]	3,262.00	14,223

[a]Reference No. 27, page 1.

[b]Reference No. 76, page 44.

[c]Beds must be at least 42 inches thick to be allowed in this category.

[d]Assumes a 50% recoverability factor, i.e., 50% of the original tonnage in the ground is lost during mining and processing.

available at the time of its compilation, will probably be found to be somewhat smaller than the true total reserves of the state, as the estimate covered only about 4000 square miles out of the 20,000 square miles of Pennsylvanian bedrock occurring in the state. Restriction in coverage of the estimate was necessary because very little information concerning the thickness and areal extent of coal deposits exists outside areas currently being mined. All data outside these areas comes from the few water wells which have fortuitously penetrated coal seams, hardly an appropriate method of accurately determining coal reserves of 16,000 square miles of potentially coal-bearing rocks. It is likely that additional reserves will be discovered in the future in currently unmined areas.

TECHNOLOGY IN THE INDUSTRY

While some progress has been made within the Iowa bituminous coal industry toward increasing the level of sophistication of the technology used in production, the individual mines are generally too small to support major advances. The technology currently in use may be conveniently separated into three sections: exploration technology, mining technology, and product preparation technology.

Exploration Technology

Most exploration is carried out within the boundaries of the known coal producing regions of the state as illustrated in Figure 14. As a unit, the industry earmarks less than 1% of its total annual budget for exploration.[22] The mining companies now operating in Iowa apparently either feel that they currently hold sufficient reserves to meet their projected short and intermediate term needs, or they simply cannot afford to do much exploration due to low profitability.

Current exploration efforts are by and large conducted on an empirical basis, in most cases without benefit of direct professional geologic assistance. The companies attempt to locate deposits within areas where general knowledge of the depth to commercial seams and of their mode of occurrence is good. Once having picked a target area empirically, they drill it to determine the presence or absence of coal, its thickness, and its quality. Thus, most of the cost of exploration is merely the cost of drilling, and the results of exploration are hit-and-miss until a drill

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[22] Reference No. 78, page 12-1 to 12-11.

penetrates a suitable coal seam. Further drilling is usually clustered about the discovery hole to determine variations in thickness and quality of the deposit and its areal extent.

The costs of drilling vary with the diameter and depth of the holes and with the method used to drill them. The cost per foot becomes less as the depth of the hole increases and as the diameter of the hole decreases, regardless of drilling method. Exploratory drilling is usually contracted to local drillers, the most common type being rotary drilling of 2 1/2-inch diameter core, at a cost ranging from about two to ten dollars per foot depending on the depth of each hole and the number of holes included in the contract.[24] It is obvious that the deeper holes necessary for testing of deposits to be mined in the subsurface are more critical in their placement, a factor intensified by the usual operation of drilling programs on a fixed amount of money, resulting in the availability of fewer holes than could be drilled on a shallower deposit. No alternative methods of locating deposits have been used in Iowa, to the author's knowledge. Study of possible alternative methods by geologists and geophysicists would appear to be in order.

Mining Technology

Shallow deposits

Coal deposits which are not too deeply buried beneath glacial material and/or rock are strip mined. The depth to which overburden can be economically stripped varies with the quality of the coal in the seam and with the

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[24]Reference No. 81 page 93.

type of overburden, rock being in most cases more difficult and expensive to remove than the looser glacial material. The major limiting factor, however, is the thickness of the seam in relation to overburden thickness. In Iowa the trend since 1945 has been toward mining of deeper seams. This trend is a result of the exhaustion of the shallower deposits and of the increasing mechanization of mining operations. In 1946 the average thickness of stripped overburden was 37.6 feet; this changed to 26.3 feet in 1950, 36.9 feet in 1955, 41.0 feet in 1960, and 51.2 feet in 1965.[25] A current rule of thumb with respect to stripping is that one foot of overburden may be economically removed for each inch of coal in the seam.

The procedure involved in stripping is simple and consists of six sequential steps: removal of overburden, blasthole drilling of the exposed coal seam, blasting of the seam, loading of the coal into trucks, transport of the coal to the preparation plant or tipple, and backfilling of the cut. Depending on the size and depth of the deposit, the type of equipment used and the number of personnel involved in actual mining are variable. Some operations have required only two or three personnel, explosives, a tractor-mounted front-end loader, and a truck. However, the larger Iowa operations use heavier equipment such as:

1. Draglines of variable size (depending upon the depth of cut necessary) for removal and backfilling of overburden;

2. Cat-tread or rubber-tired tractors equipped with blades for overburden grading or high-angle front-end loaders for loading of broken coal into trucks;

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[25]Reference No. 76, page 623.

3. Small rotary drilling rigs, either truck or trailer mounted, for in-pit blasthole drilling;

4. A number of trucks of variable size for transportation of coal from the pit to the preparation plant or tipple. In most cases, these trucks are leased with drivers from a local haulage firm. Therefore only 8 to 12 operating personnel are needed in a mine producing on the order of 100,000 short tons of coal annually.

Deeper deposits

Deposits too deep to be stripped economically must be mined by subsurface methods. Iowa's subsurface operations are restricted to places where uniformly thick coal seams are present over a relatively large area, since the start-up costs of subsurface operations are considerably greater than those of stripping operations and because, once in place, a subsurface operation cannot be moved to a new locality as can a stripping operation.

The fixed nature of subsurface operations and the additional expenses involved in mining in the subsurface are, however, offset by the fact that the mines can operate continuously without interruption or disruption of operations due to snow, heavy rains, and the like, and by the fact that the value of their product is somewhat higher than that of strip mines. The latter is due to the generally lower moisture content and cleaner condition of coal produced from the subsurface. In 1965 subsurface Iowa coal was valued at an average of $4.07 per short ton, FOB the mine, while a similar valuation of stripped coal was $3.81 per short ton. Eighteen and eight-tenths percent of Iowa coal production came from subsurface mines and 81.2% came from strip mines in 1965, as opposed to 65% from subsurface mines and

35% from strip mines nationally.[26]

The equipment used in subsurface mining is unlike the equipment used in strip mining; virtually the only identical items are the coal haulage trucks. Subsurface mining requires construction of a shaft and appropriate hoisting apparatus or construction of an inclined entry, the installation of electric power wiring for lighting and operation of mining machinery (most machinery is now electric-hydraulic), and the installation of mine-gauge railroad track to accommodate ore cars and their motors (haulage engines), all before actual mining can commence. The normal sequence of steps in subsurface mining, and the equipment needed, is as follows:

1. Horizontal undercutting of the working coal face to a depth of up to 12 feet, with possible cutting of a similar, vertical "kerf" near one wall. Cutting of the coal is necessary to prepare the coal for blasting, as such cutting relieves the shot, resulting in better breakage with less powder. The cutting machinery is similar both in appearance and in operation to a chain saw enlarged several tens of times;

2. Drilling of shot holes in the face along a pattern designed to break the coal to the desired average size and to place it slightly away from the new working face to facilitate loading. Drilling of shot holes is done using rotary drills mounted on a self-propelled vehicle;

3. Breaking of the coal either by use of explosives or by use of bursts of high-pressure compressed air;

4. Loading of broken coal from the face pile into transporter vehicles (mucking). This is accomplished using special loading machines

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[26]Reference No. 76, page 66; Reference No. 48, page 15.

equipped with moving arms which scoop the coal onto a conveyor belt which carries it upward into the transporter;

5. Movement of the coal from the face to the end of the rail trackage with the transporter, followed by off-loading into rail cars using the transporter conveyor;

6. Haulage of the coal by train to the shaft bottom, where the cars are dumped into the ore skip for hoisting to the surface. In mines with inclined entries, the ore is transported directly to the surface by the train where it is dumped;

7. Shortly after mucking is complete, a special drilling machine is brought to the face to drill small holes into the structurally unsound shale roof. The same drilling machine is then used to tension rock bolts placed in the drilled holes. These bolts stress the roof rock, increasing its strength.

All of this machinery must be compact and low-slung due to the small size of the mine passageways, and must meet rigorous safety regulations designed to minimize or eliminate the chance of sparking of electrical equipment in a potentially flammable or explosive atmosphere.

<u>Geologic problems in mining</u>

Occasional physical problems arise in the mining of Iowa coal deposits as a result of the geologic conditions present during the formation of the deposits. These problems are primarily of a structural nature. The most often encountered structural problem is the lack of flatness of most Iowa coal seams. The coal was initially formed atop an erosion surface, and assumed the shape of the surface during coalification. Relief on such surfaces is usually only a matter of five to ten feet, but undulating seams are difficult to follow in the subsurface and difficult to strip cleanly. A cross-sectional view of such a deposit is presented in Figure 15a.

A second problem is the lensatic nature of most of the deposits. Since these were formed principally in stream valleys, and thus tended to fill the valley floors, the deposits are thicker in their center and thinner at the edges, eventually giving way to other types of rock. Thickening and thinning of the deposits presents problems very similar to those arising from conformance of the coal seam to an undulating depositional surface.

The three remaining major structural problems, "horsebacks", "pinches", and faults, present problems to subsurface operations only. "Horsebacks" are projections of depositional surface rock into or through the coal.[27] Such a projection can present a wall-like obstacle as encountered in the subsurface, and is difficult to tunnel through, around, or over.

When intra-Pennsylvanian erosion occurred above and parallel to a "horseback", and when the erosional channel was subsequently filled with sediments, a "pinch" developed in the coal seam as it is encountered in subsurface operations.[28] A "pinch" requires widening to allow passage of mining equipment. Figure 15b illustrates a "horseback", an intra-Pennsylvanian erosion channel, and a "pinch".

A fault, by definition, is a rock fracture along which displacement of the rock has occurred parallel to the fracture plane. Large faults are

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[27] Reference No. 25, page 27.

[28] Reference No. 25, page 30.

major problems in subsurface mining, as the trackage and other mining equipment must be raised or lowered from the initial mine level, resulting in production delays and added expense. Also, the rock in the zone of faulting is often shattered or at least weakened, so that roof support is more critical in these areas. A cross-section of a faulted coal seam is presented in Figure 15c.

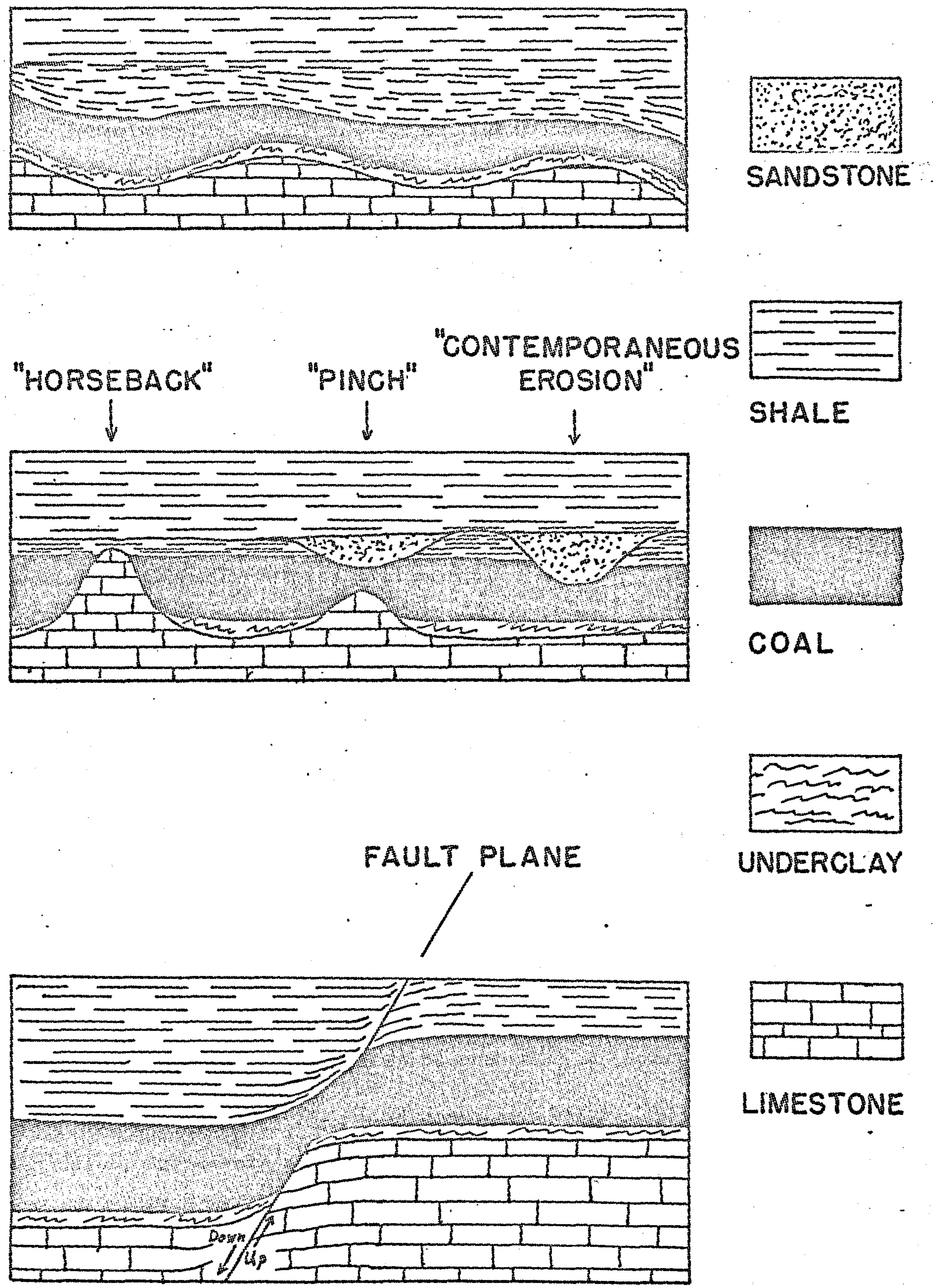
On the basis of present knowledge, perhaps the most important geologic problem encountered in Iowa arises from combination of the previously discussed lensatic nature of the deposits with their small size. Unlike the mines operated in Illinois and elsewhere, the Iowa mines are restricted to mining of a small area, and then must transfer their equipment to another similar small area. This process is inefficient, disrupts production somewhat, and presents a serious drawback to establishment of large-scale coal mining operations of a size sufficient to deliver, for example, a million tons a year at reasonable prices on a long term contract (twenty to thirty years) basis. A contract of this variety is required by the electric utilities before they will commit funds to the construction of large power plants similar in size to those serving metropolitan areas or whole sections of states. The solution to this problem will involve more exploration than is currently being engaged in to find larger coal deposits, investigation on the economic and technical level of the possibility of using multiple sources of coal on an organized basis over a lengthy period of time through simultaneous operation of several mines by a single firm or group of firms with common preparation and shipping facilities, and of research aimed at reducing the production and transport costs of the smaller, lensatic deposit mining operations.

Figure 15. Structural obstacles to subsurface coal mining in cross-section

a. Conformance of coal seam to pre-depositional erosion surface resulting in an undulating coal seam

b. "Horseback", "pinch", and intra-Pennsylvanian ("contemporaneous") erosion channel

c. Fault in coal seam and surrounding rocks. (Normal fault).


SANDSTONE
SHALE
COAL
UNDERCLAY
LIMESTONE
"HORSEBACK"
"PINCH"
"CONTEMPORANEOUS
EROSION"
FAULT PLANE
Down
Up

Product Preparation Technology

The remaining Iowa coal producers have managed to survive in competition largely because they have increased the size and efficiency of their mining operations through the years. They have devoted little attention to product preparation in doing so. Essentially, the only preparation which Iowa coal receives prior to delivery is crushing to a contract specified size. This lack of preparation is at odds with the trend in the national industry, which has consistently been toward extensive additional tailoring of the coal at the mine before shipment to the user. Lack of such preparation has probably contributed to reduction of the market for Iowa coal. It is instructive to compare coal treatment procedures used in Iowa with a successful competing state, Illinois.

In 1965, 78.4% of Iowa-produced bituminous coal was crushed to size, as opposed to 50.3% of Illinois-produced coal. The Illinois mines mechanically cleaned (by either washing or flotation) 82.2% of their coal, while Iowa mines cleaned none of theirs. The Illinois mines treated 9.3% of their coal for dust; Iowa mines treated only 0.6% of their coal for dust. The Illinois mines thermally dried 18.5% of their coal, while Iowa mines thermally dried none of theirs.[29] Since all of these methods of product treatment increase the quality of the product, and therefore increase its value to the consumer, it would appear that serious investigation of the engineering and economic aspects of treatment of Iowa coals should be undertaken by the industry at once in preparation for possible market expansion, and before out-of-state coal makes further inroads into existing markets.

[29]Reference No. 76, page 106-117.

ANALYSIS OF PRODUCTION COSTS

The largest part of the price of coal to the consumer is accounted for by the production costs of the mine. Unfortunately, little reliable information about these costs is currently available due to a number of factors which are all too often encountered in economic studies. If anything, these factors, which are listed below, were found to be even more restrictive than usual with respect to the coal industry:

1. Government records are largely inadequate due to limited coverage and/or lumping of data into broad categories to insure privacy of business data;

2. Private records held outside the companies involved are usually confidential, as the owners of the various mines are reluctant to part with cost information which, if it fell into the wrong hands, could lead to severe complications in their business dealings. The Iowa coal producers seem to be a bit more secretive than most, possibly because the mines are family owned;

3. When cost information does become available it is usually far out of date and incomplete.

The government-collected cost information currently available for the coal industry of Iowa consists of data published by the U.S. Bureau of Mines and by the Bureau of the Census. Unlike most states which have operating mineral industries, information is not collected by the State of Iowa, with the exception of annual production figures and employment information.

On a national basis, the Bureau of Mines recently developed an index of major input expenses for bituminous coal mining, with its base period of 1957-1959 equal to 100. The index subsequently declined to 85 in 1965 indicating that the cost of producing a ton of coal had declined.[30] It is doubtful that this decline affected the Iowa industry much due to the nature of its operations and their small size. The 1958 Census figures for the Iowa bituminous coal industry are the most recently available cost figures. These are presented in Table 4.

During 1958 the value of shipments and receipts was $4,867,000 yielding revenue after deduction of the production and capital expenses listed in Table 4 of $1,007,000. Royalties paid to landowners (nearly all Iowa coal properties are leased by the mining firms), sales costs, transportation costs, and taxes are not given in the census figures, and have not been deducted. Exact per-ton averages of these costs are not available. An estimate would be that the royalties to landowners were about 20 cents per ton for the 898,716 tons of stripped coal and 7 cents per ton for the 292,572 tons mined by subsurface methods.[31] Sales costs may be estimated at approximately 12 cents per ton. These costs reduce the surplus revenue figure to $666,000. Both transportation costs and federal and state income taxes remain unknown and undeducted. It is likely that in the cases of the smaller mines the surplus revenue remaining after deduction of these costs was very close to zero, and quite possibly negative.

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[30]Reference No. 76, page 27.

[31]Reference No. 46, page 8-9.

Table 4. Production costs of the Iowa bituminous coal industry, 1958[a]

Item	Cost in $	$/short ton	% of total $
Wages to production and development workers	1,388,000		34.7
Salaries and wages to management and other	115,000		3.0
Labor subtotal	1,453,000	1.24	37.7
Purchased fuels and electricity	971,000		25.2
Minerals received for preparation	262,000		6.8
Contract work	129,000		3.3
Purchased machinery, installed	479,000		12.4
Supplies subtotal	1,841,000	1.56	47.7
Development and exploration of properties	8,000		0.2
Plant and other construction, machinery, and equipment	558,000		14.5
Capital expenditures subtotal	566,000	0.48	14.7
Total production expenditures	3,294,000	2.80	85.4
Total expenditures	3,860,000	3.28	100.1

[a]U.S. Bureau of the Census, Census of the Mineral Industries, 1958. Reference No. 78, page 12-1 to 12-11.

ANALYSIS OF MARKETING COSTS AND PROCEDURES INCLUDING TRANSPORTATION TO USE SITE[32]

Sales Procedures

Iowa coal is sold by one of two alternative methods: direct sale by the individual mining companies to the consumers, or sale through an intermediary coal brokerage firm. Most of the coal (68% of the total 1968 output) is sold by the latter method.[33] Virtually all of the individually significant consumers of Iowa coal purchase it through a contract arrangement with the various brokerage firms.

The principal use of Iowa coal, as determined by its rank and purity, is in steam generation. About 95% of the total output is consumed in this use. This requires relatively large, continuous, dependable supplies of coal, precluding except in the case of small steam plants dependence of the plant on the output of a single small mine. All Iowa mines may be considered small. For this reason, most of the consumers prefer to enter into contracts with coal brokerage firms which guarantee adequate supplies on a long range basis. The sales contract specifies among other details the price of the coal per short ton delivered, the delivery schedule, and acceptable quality standards.

The brokerage firm is bonded to ensure compliance with the terms of the sales contract. Penalties are applied for failure to meet the various

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[32]The author is indebted to William J. Evans for much of the factual matter contained in this chapter. The comments on transportation, however, are entirely those of the author.

[33]Reference No. 23, page 608.

quality standards. Usually if the coal fails to yield upon analysis a lower limit of about 9,250 BTU per pound a penalty is applied. Similar penalties are applicable for coal containing more than about 25% combined impurities and for excessive moisture content.[34] If the coal exceeds the specified quality standards appreciably, a premium is paid, as less coal of high quality is necessary to generate a given number of BTU's. It is important to note that the penalties are always much steeper than the premiums.

Having acquired its sales contracts for a given period of time, the brokerage firm in turn contracts with as many mines as are necessary to fulfill its commitments. If a producer has a poor history the brokerage firm may require the producer to be bonded to it as it is bonded to their customer. The production contract duplicates in essentials the sales contract. Thus the brokerage normally acts only to bring the coal producer and the consumer together. However, if the producer fails to supply the coal as per contract, for whatever reason, the brokerage firm is obligated to correct the deficiency. For the use of its services, the brokerage firm charges a flat fee of between 10 and 20 cents per short ton, normally around 15 cents at the present time. All penalties and premiums accrue to the company or mine producing the output for any given consumer. Based on verified sales through brokerages at a fee of 15 cents per ton, the coal brokerages' arrangements for Iowa coal sales in 1968 brought them a total revenue of about $90,000.

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[34]Note that the coal consumers are interested in cost per million BTU _as burned_, while the coal producers are interested in price received per short ton _as delivered_.

Direct sale of coal by the mine to the consumer is limited to the smaller producers, most of which sell less than 50,000 short tons of coal annually. Their sales costs vary from rather high to practically nil, depending on their individual market conditions. A number of the small producers supply local markets which are more-or-less captive due to economies of location arising from low local transportation costs. Most of these firms have sold to their current customers throughout the period considered here and will continue to do so in the foreseeable future. Their sales costs are low. Small mines without captive markets have difficulty selling their product except when a coal brokerage firm must resort to buying from them due to temporary production difficulties encountered by its contracted mines. The sales costs of these mines are generally rather high.

Transportation

Considering that approximately one-eighth to one-third of the purchase price of coal consists of transportation costs, it would at first appear that transportation deserves a chapter of its own rather than inclusion in the chapter on marketing costs. These transportation costs, however, are paid directly by the coal producers since, unlike many other commodities, coal is purchased on a delivered basis. Such costs, variable in magnitude dependent upon destination and type of carrier, should be viewed as a part of the coal producer's marketing costs, and will therefore be included here.

There are three principal types of coal carriers: railroads, trucks, and barges or colliers. On the national level, the relative percentage of total output carried by each has remained fairly constant through the past few years. This is not the case in Iowa. The latest available coal transport percentages for the nation, for Iowa, and for the U.S. average from 1956-1965 are given in Table 5. None of the Iowa coal was shipped by water carrier.

Table 5. Percentage of total coal output shipped by alternative carriers[a]

Type of carrier	U.S. (1965)	U.S. average (1956-1965)	Iowa (1965)
Railroad	72.6	73.8	70.1
Truck	13.3	12.9	27.6
Water and used at mine	14.1	13.8	2.3

[a]Data from Reference Nos. 56-77 inclusive.

The truck carrier figure for Iowa is higher than the national average probably due to lack of alternative intrastate water transport and to the fact that the mines must ship to some points which are not located near railroads or are so close to the mine that rail shipments would be extremely inefficient.

It is nevertheless clear that rail freight costs have the greatest impact on the Iowa coal producers. Since the railroads constitute a potential monopoly, they are regulated as public utilities by the Interstate Commerce Commission and the commerce commissions or transportation departments of the various states. These public bodies set the maximum freight rates which the railroads may charge. The individual carriers may unilaterally lower their rates, but they may not raise them above a certain set point. The major objectives of regulation are two-fold: to protect the consumer against unreasonably profitable monopolies, and to keep the railways functional in the event of a national emergency. The procedure by which rates are established with these objectives in mind have evolved over the years into a rather complex pattern.

The first step in establishment of a new rate or rate structure is the presentation of operational railroad data supporting the need for a new rate (which is invariably a rate increase) to the appropriate regulatory body. In Iowa this is the Iowa Commerce Commission. If the commission believes that the railroad is justified in its demand for a new rate, it authorizes the railroad to formulate the new rate or rate schedule. When this is reported back to the commission it is only then open to discussion, opposition, or agreement by the shippers and their customers. This lopsided procedure gives the railroads a decided advantage from the start. Due in large part to the initial devising of rate structures by the railroads these are exceedingly complicated and largely nonsensical. They begin on a very rational basis: straight ton-mile rates. These apparently are inflated rates and are seldom, if ever, the real rates for the bulk of intrastate shipments. There are extra charges for multiple carriers, switching, and other services due to the necessity for travel in other than a straight line down a single track. As a result, while the ton-mile rate table fills but one page, the actual rates for coal ("specific commodity rates") require eight pages of fine print, listing specific per-ton charges from every point of origin to several destinations in central and southern Iowa. These rates differ markedly from the ton-mile charges over the same distance, averaging some 30-60% lower than the ton-mile charges. The reader is referred to samples of both types of rates and a comparison of rates for shipment from Iowa mines to Des Moines given in the Appendices. At least one across-the-board rate increase of 15 cents per ton to all destinations has been levied since the Tariff was published in 1961. The specific commodity rates appear to be the highest rates which the coal shippers can afford to pay without losing money. Yet the railroad position on the rate structure is set forward in the Tariff:

> These rates are considered by the interested carriers to be unreasonably low, discriminatory against interstate commerce, preferential of intrastate commerce, and are published under protest solely to avoid fines and penalties provided in the Iowa statutes.[35]

It is evident that the railroads would rather carry bulk commodities with relatively low values (such as coal) interstate than intrastate, as they receive larger total revenues by doing so and benefit from longer, more efficient hauls. To this end, the more reasonable specific commodity rates cover only central and southern Iowa destinations, parts of the State which are sparsely populated, underdeveloped industrially, and located close to the coal mines. The much higher ton-mile rates currently cover any shipment from Iowa mines to the population and industrial centers in eastern Iowa. This apparently prohibits economic shipment of coal from most Iowa mines to these centers, with the result that coal used in eastern Iowa usually must be imported interstate by rail or water. Most of it comes from Illinois mines.

This situation is inequitable in the author's opinion, and should be

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[35]Reference No. 54, page 67.

corrected. The apparent effects of the current rate structure on the industry are:

a. The rates allow only small profit margins to most Iowa coal mining firms.

b. By limiting the profits, the rates discourage entry into the industry.

c. They discourage expansion of existing coal producers through making the acquisition of capital difficult (indirectly) and by limiting the possibility of acquiring new markets.

d. The structure limits the market area within which each producer can supply current markets at competitive prices. As a consequence, even the largest Iowa coal mines supply but one or two power plants.

Considering the rate structure situation, it is surprising to note that in 1955 shipment of Iowa coal was roughly divided half and half between rail and trucks, whereas in 1965 shipment was about three-fourths by rail and one-fourth by truck. The author has found no concrete documentation to explain the increase in rail shipment. Whether the shift is due to lack of interest in transporting coal on the part of the trucking industry or to aggressive protection of their existing business by the railroads is unknown. At present the large users of coal, principally the power utilities, have little choice other than to receive their coal by rail.

The author is well aware that the preceding comments on the rail freight structure for coal are based on a very limited examination of a complex subject. Therefore, only tentative conclusions are to be drawn. However, this inspection of currently available data indicates that a serious, detailed study of the rate structures may be needed to clarify the Iowa situation as a first step to assistance of the Iowa coal industry.

ANALYSIS OF COMPETITION

The Market for Iowa Coal

During 1965, 72.5% (724,000 short tons) of Iowa's coal production was purchased by electric utility companies, about 0.2% (2,000 short tons) was purchased by retail dealers, and 27.3% (272,000 short tons) was purchased for all other uses, mainly space heating of large buildings.[36] Since 1965, consumption of Iowa coal by utility companies has increased and consumption for space heating and retail sale has remained about constant, indicating that any growth of the Iowa bituminous coal industry, at least in the short run, is dependent upon increased use of Iowa coal by the utility companies.

As of 1963, eighteen utilities operated 38 generating plants in Iowa with a combined installed capacity of 1,844,000 kilowatts. These facilities utilized about 2,351,000 short tons of bituminous coal, about 46,000 barrels of fuel oil, and 49,301,000,000,000 cubic feet of natural gas to produce a net generation of 7,644,000,000 kilowatts of electric power during 1963. Assuming that the average as-burned heat content of a pound of coal is 10,482 BTU, of a gallon of oil is 142,753 BTU, and of a cubic foot of natural gas is 1,006 BTU, total heat utilization in 1963 was about 99,181,100,000,000 BTU. Cost of the coal during this period was 25.9 cents per million BTU, FOB the plant, and 27.1 cents per million BTU as-burned. Comparative costs for fuel oil and natural gas were 62.8 cents and 26.5 cents, respectively.[37] Coal was therefore slightly cheaper to use than

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[36] Reference No. 76, page 139.

[37] Reference No. 32, page 8.

natural gas, although each of these fuels contributed essentially 50% of the total BTU for the year.

These figures indicate the degree to which the various alternative fuels were price-competitive in the Iowa utility industry in 1963. The cost picture has not changed substantially since 1963, as no significant improvement in the cost of producing a kilowatt-hour of electricity has been made since about 1960.[38] It is doubtful if any major improvement is forthcoming in the near future.

Internal Competition

Internal competition, the competition between and among producers of Iowa coal, is of a limited nature, and is principally controlled by two interdependent factors: size of the individual mining operations, and relative transportation costs from various mine sites to various power plants, with the latter factor largely governing the former. In general, only those mines with favorable transportation costs can obtain contracts to supply large tonnage to utility companies (production costs are generally constant from mine to mine), and only those mines with such contracts are capable of achieving the size necessary to supply large tonnage reliably.

As supportive data to this analysis, consider the present concentration of production in the Iowa industry: seven mines produced more than 50,000 tons each, and seven produced less than 50,000 tons each in 1968. Average production per mine in the large tonnage group was 62,740 tons,

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[38] Reference No. 76, page 137.

while average production per mine in the lower tonnage group was only 25,866 tons. The four largest mining firms (36.4% of all firms) produced 68% of the total 1968 output, while the top five firms (45.5% of all firms) produced 79% of the total output.[39] Almost invariably, the larger firms supply the electric utilities, and the smaller firms supply the space heating market. It is clear that internal competition is controlled by the freight cost structure; the freight cost structure is external to, rather than internal to, the industry, resulting in a rather curious situation.

External Competition

External competition may be defined as competition with out-of-state producers of bituminous coal and with out-of-state producers of alternative fuels.

Competition with out-of-state coal producers

The three factors adversely affecting the ability of Iowa coal producers to compete successfully with out-of-state coal producers are:

1. The structure of interstate and intrastate rail-freight transport rates for bulk coal are such that the large mines located in Illinois can ship their coal into eastern Iowa on a better than price-competitive basis.

2. Since the power utilities are not interested primarily in per ton costs, but rather in costs per million BTU, coal from out-of-state producers which delivers slightly more BTU's per pound than Iowa coal can be competitively shipped interstate to eastern Iowa even if the transportation cost

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[39]Reference No. 50, page 11.

per ton is slightly higher on interstate shipments than on intrastate shipments;

3. The out-of-state mines in competition with in-state producers generally do much more in the way of product treatment than do the in-state producers. (Review information on comparative product treatment presented in the chapter on industry technology.) Since washed and/or thermally dried coal delivers more BTU's per pound, and has lower impurity content than untreated coal, it is more economical to use for power generation. Thermally dried coal also weighs less to transport, resulting in lower transportation charges.

In terms of magnitude, the Iowa power utilities purchased about 3,000,000 short tons of bituminous coal in 1963, about one-third of which was Iowa coal and two-thirds of which was purchased from out-of-state sources. No figures are available for the space heating market, but it is reasonable to assume that relatively less coal was imported for this use. Most of the coal sold in Iowa on a retail basis is imported from out-of-state, as Iowa coal is not well suited for this use. Although this is a declining market, some 714,000 tons were imported into Iowa in 1963 for this use.[40]

<u>Competition with out-of-state producers of alternative fuels</u>

Competition with alternative fuels of out-of-state origin is difficult to evaluate adequately without the availability of more numerical data than is currently available. However, it is safe to generalize that unless the cost of coal per kilowatt becomes relatively lower with respect to natural

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[40] Reference No. 74, page 153.

gas, the present 50-50 ratio of coal and gas BTU inputs will continue in the foreseeable future. Treatment of Iowa coal at the mines might increase demand for it relative to gas by lowering the as-burned cost per million BTU. For instance, moisture increases the possibility of spontaneous combustion occurring in stockpiles, and makes pre-use thawing of stockpiled coal necessary in winter. Thermal drying of the coal would enhance its storage characteristics to a considerable degree.

NEW DEVELOPMENTS AND THEIR EFFECTS ON THE INDUSTRY FUTURE

Recent and Current Research

Broad-spectrum research on coal production and use is conducted on a continuing basis by the United States Bureau of Mines, in cooperation with various other Federal and State agencies and with industry. Current research includes studies involving the effects of coal mining and use on the environment; coal mining techniques and machinery; health and safety improvements in mining; coal storage, preparation, and transportation; means of increasing efficiency in production of electricity with coal burning power plants; the chemical properties of coal and the chemical derivatives of coal; and means of producing synthetic natural gas from coal.[41] The results of recent research and the promising preliminary results of several current research projects will be of importance to the Iowa bituminous coal industry during the next two decades, particularly in the areas of desulfurization of coal (removal or reduction of pyrite content), coal cleaning (removal or reduction of ash content), coal drying, and use of coal in the synthesis of natural gas.

Since the efficiency of modern coal combustion devices is quite high even with the lower quality coals (as a result of many years of research and improvements) the major objections to the use of Iowa bituminous coal for large volume heating applications are due to the relatively poor storage characteristics of the coal and to atmospheric pollution problems. Use of already well-developed techniques of thermal drying at mine preparation

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[41]Reference No. 37, page 1-84.

plants would solve much of the storage problem. This process should be investigated. A coal washing plant operated in Iowa for about five years early in the century, but operations were discontinued because of exorbitant loss of coal during the process. Flotation and hydrocyclone methods have since been developed which permit higher coal recoveries and better cleaning. Two-stage hydrocycloning has been found satisfactory as long as slurry density is carefully controlled.[42]

The most troublesome contaminant in Iowa coal, however, is pyrite. When pyrite is burned along with the coal, the sulfur in it combines with oxygen from the air producing sulfur dioxide, a poisonous gas, which then passes through the stack into the atmosphere. Two approaches have been proposed and are currently being developed for removing the pyrite before the coal is burned. Magnetic separation has been found effective, but is costly.[43] Preliminary results of studies of centrifugal separation indicate that two-stage centrifugation can reduce the pyrite content of some bituminous coal efficiently.[44] This is a far less costly process than magnetic separation, as well as simpler, and if the method remains successful when final testing results are complete it should be investigated with respect to beneficiation of Iowa coals. The second approach to the problem is the removal of sulfur dioxide from the flue gases with various absorbents such as alumina. This process promises to be effective, although more expensive. The more economic procedure appears to be centrifugation.

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[42]Reference No. 34, page 1.

[43]Reference No. 22, page 1.

[44]Reference No. 37, page 10.

Future Energy Demand

An extremely well prepared synthesis of projections of United States energy demand and probable supply for the period from 1969 to 2000 was recently presented by Henry R. Linden to the 1969 Lignite Symposium.[45] This is probably the most reliable forecast in existence. Linden indicates that demand for natural gas will increase from 20.1 trillion cubic feet per year to 41.2 trillion cubic feet per year during this period, based on 1032 BTU per cubic foot of gas. Total energy consumption will increase from 63 quadrillion BTU to about 170 quadrillion BTU during the same interval. Forecasted demand for coal, based on current technology, indicates a drop from about 21.5% of the total demand in 1970 to about 12% in 2000. However, analysis of natural gas supply indicates that economically recoverable natural gas supplies with access to U.S. markets will be exhausted around or shortly after the year 2000. Linden concludes that among the supplemental sources of natural gas including imported pipeline gas from Canada and Mexico, tanker importation of liquefied natural gas, and synthetic pipeline gas manufactured from coal, the latter is by far the most abundant source at potentially competitive costs. The author is in agreement with this conclusion. Linden estimates that consumption of coal could increase from 530 million tons per year in 1970 to a maximum of 1840 million tons per year in 2000, based on the use of 70 million tons of coal per trillion cubic feet of synthetic pipeline gas produced.

Two methods of producing synthetic natural gas are currently entering the pilot plant stage. Fluid-bed gasification is the most likely prospect

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[45] Reference No. 29, page 1-18.

for pipeline gas, but at present this process is plagued with a low conversion factor. This will undoubtedly be raised after further testing. The alternative method, hydrogasification, has met with initial success. The first attempt with this process, which essentially combines hydrogen and coal to form methane and other alkanes, easily achieved 52% conversion in a one-step pilot plant. If either of these processes becomes commercial within the next few years, as they most certainly will, the Iowa bituminous coal industry could benefit greatly from its mid-continent location and relatively large coal reserves.

DISCUSSION AND RECOMMENDATIONS

Throughout its history the Iowa bituminous coal industry has experienced dynamic change. It grew rapidly during the early Twentieth Century in response to rapid expansion of markets for Iowa coal and declined continuously after 1917 as these markets progressively contracted, particularly during the post World War II period. The industry failed to develop new markets replacing those which were lost and failed to modernize its technology and business practices at the same rapid rate as did its competitors. Based on projection of statistical data measuring the decline of the industry, it is reasonable to expect that by 1980:

a. Only one or two coal mining firms will remain in Iowa;

b. Total industry production will not be appreciably greater than the current total;

c. Employment in the industry will be less than current employment.

The industry will no longer be a group of similar firms, but will be in the hands of one, or possibly two producers. This could be an overly pessimistic projection because it is based solely on past performance. It does not take into account future developments which in the aggregate could lead to at least slight improvements in the industry's position. It may be considered as the worst possible future for the industry, but it is based on industry data as reported and analyzed.

Future developments in the industry can take but two pathways: random and planned. By the random path the industry can continue producing in its current unorganized, relatively inactive state in the hope that random future developments will be for the better. There is an equal chance that they will be for the worse, a chance which the industry can ill afford to take. The alternative choice is that of a planned path. A planned path, by the implementation of previously tested and proven programs, is virtually assured of improving the industry position. The only uncertainty is the degree of improvement; the more carefully the programs are organized and the better they are executed the greater will be the improvement. The author believes that a planned path is the proper course for the Iowa bituminous coal industry, and that use of such a path is imperative during the next few years. The following material recommends the adoption of specific programs which should (and must) be included in such a planned path, and details the tasks which the industry should accomplish during the next ten to fifteen years.

Organization

One of the major problems discovered during the course of this study was lack of organized effort to solve common industry problems. During the postwar period the currently active coal producers directed their attention toward increased production efficiency, devoting little time or energy toward other aspects of the business. The industry did not work as a unit toward attainment of beneficial common goals. Meanwhile the competition organized and devoted much effort toward modernization of their business practices, sought new markets, and supported or conducted technical studies which resulted in operating efficiencies and higher profits. Producer associations were formed in most of the coal states in response to the need for organized activity. Such an organization is a pressing need insofar as the Iowa industry is concerned, and should become the keystone of future industry development.

The general goal of the association should be to solve problems (or assist in their solution) common to the member firms such as finding and developing new markets, developing a good picture of the Pennsylvanian geology of Iowa to help in evaluation of coal prospects, supporting studies of new means of locating and defining coal deposits, finding ways of coal transport other than by rail if practical, and assisting in reduction of the cost of coal transport. Among specific duties the association should:

a. Act as a gathering agent and clearing house for information about the industry and for information which might be of use to the industry.

b. Act as a spokesman for the industry in government legislative and regulatory hearings (particularly freight rate hearings). It should not act as a lobbyist in the ordinary sense, but rather as a source of reliable, unbiased information.

c. Act as a coordinator of, and a participant in necessary special studies of industry problems.

d. Act as a public relations agency for the industry, on a limited scale.

In order to fulfill these objectives, the association must be fully supported by all of its members. If such support is received, it will truly represent the industry and will be capable of making important contributions to the welfare of the industry.

Legislation

It is obvious that the State of Iowa needs to improve its collection of vital data regarding the Iowa bituminous coal industry. As cited earlier, the only information currently required of the mining firms is data on production and employment. Most coal producing states require more detailed data about these variables as well as a variety of additional data. Detailed data is an absolute prerequisite in economic studies and is necessary to knowledgeable, fair treatment of the industry by government. It is recommended that the Iowa Department of Mines and Minerals institute legislation to require the annual submittal of the following data by each mining firm:

1. Types of equipment in use and equipment capacity
2. Monthly production
3. Monthly employment (production workers)
4. Management employment
5. Total wages and salaries paid to production workers
6. Total payroll
7. Cost of normal (recurrent) operating supplies
8. Cost of contracted services
9. Cost of minerals received for preparation
10. Cost of product shipment
11. Expenses incurred for exploration and development of new properties
12. Capital investment data
13. Percent of total production purchased for electric generation, space heating, and other uses
14. Percent of total production shipped from the tipple or preparation plant by each means of transportation

These data should be held in confidence by the Department, being published or disclosed only in such form that specific financial data could not be traced to specific mining firms. The two exceptions to confidentiality should be:

a. If release of the data is requested by a mining firm,

b. In the event of necessity for use of detailed data by persons qualified to study industry problems (and then only with the assurance that the data would not be disclosed in a manner which could link it to specific firms).

Policies similar to this are common in the other coal producing states, and their publications and the types of information they collect should serve as a guideline (in particular the excellent publications by the State of Illinois).

Specific Studies

Many of the more technical problems common to the firms in the industry require more knowledge than is currently available before they can be solved. The industry should adopt a policy of encouraging, participating in, and supporting specific studies of these problems. The following studies are recommended on the basis of weaknesses discovered in the course of this study.

Geologic studies

The purpose of geologic studies should be broad development of the data and understanding necessary to the discovery and quantification of Iowa coal deposits. Suggested studies are:

a. A comprehensive examination of the pre-Cherokee erosion surface of Iowa, including geologic, paleotopographic, and paleostructural studies.

b. Up-dating of the Pennsylvanian stratigraphy of Iowa including lithologic, paleontologic, paleoecologic, paleobotanic, and paleogeographic investigation, leading to outlining of the Pennsylvanian history of Iowa on a modern, detailed basis.

c. A re-evaluation, description, and correlation of exposed coal seams and available coal cores and examination of previously published records for which the samples are no longer available.

d. Study of the applicability of geophysical methods to discovery and outlining of Iowa coal deposits.

For the most part these studies are long overdue. While most of them require long term efforts suitable for execution by the Iowa Geological Survey, the initial work could be done by the geologic staffs of the various Iowa universities. This would result in rapid advancement from the present low level of knowledge of the Pennsylvanian rocks of Iowa at a cost less than that of any other method for work of comparable quality.

Business and economic studies

The following are needed:

1. A detailed study of current sales procedures and costs.

2. A study of recent markets for Iowa coal, of their potential for expansion, and what can be done to expand them, including detailed study of the electric utility industry, its future needs, and its possible options in fulfilling these needs.

3. A study of possible new markets for Iowa coal.

4. A comprehensive study of bulk coal transport by each applicable means. The total costs and relative efficiency of each method should be

investigated, as well as the rate structures. The efficiency and economics of combined shipments from several small mines should receive priority consideration.

5. Application of economic analysis to specific industry problems. As an example, an analysis of the probable market for Iowa coal treated by thermal drying along with an analysis of the economics of the treatment process.

Engineering studies

An engineering study of the applicability of the various product treatment methods to Iowa coals should be made as soon as possible. The degree to which each method improves the properties of the coal should be investigated, as well as the degree of coal loss during the process. Critical path and other modern analytical techniques should be applied to simulated operation of a number of small mines feeding a single preparation plant or tipple to find the most efficient methods of operation for such a mining organization.

Industry Goals

Short run goals

In the short run the industry should initiate many of the investigations suggested above, particularly those concerned with current coal markets, coal transportation, coal treatment, and operation of multiple-source mining operations. The results of these studies should be applied to expansion of existing markets for Iowa coal. Expansion of the industry is totally dependent on expanding these short run markets.

Medium and long run goals

Over the medium and long runs the primary industry goal should be the development of new markets for Iowa coal, both within and outside of the state. Use of Iowa coal in the production of synthetic natural gas appears to be a most promising direction. Product treatment combined with lower transportation rates, perhaps through such media as unit-train shipments, would definitely result in the development of potential new markets.

Regardless of potential new uses for Iowa coal the largest single new market will be the expanded market for coal used in the production of electrical energy. All projections of future energy demand indicate that demand will approximately double every 10 to 15 years. Barring a wholesale switch to nuclear or solar power sources, and in view of the imminent depletion of natural gas reserves, coal will be of greater importance as a source of energy than it currently is. If transportation costs for imported coal should increase faster than expansion of the economy during the next few decades, small mine operations might once again become economic in Iowa. It would conceivably be less expensive to produce electric power with small, local power plants located as close to the mines as possible.

It is more likely that transportation costs will increase in step with the economy and that the current trend toward centralization of electric production at large power plants will continue. In recent years it has been less expensive to locate such a plant at the mouth of a large mine capable of supplying the plant for about 30 years and transmit the power to the customers, rather than ship coal to local plants. Design of these large plants requires complete knowledge of the coal properties such as its BTU, sulfur, and ash content, the reserves available, and a breakdown of the costs for the entire life of the plant and coal supply. These large plant operations require the existence of large coal deposits of a size presently unknown in Iowa.

The localized lensatic nature of our coal deposits does not appear to favor development of mine site plants. The coal deposits occur at definite horizons which to date have been inadequately prospected to ascertain whether the lensatic nature is characteristic of Iowa coal or whether larger, more continuous coal deposits exist. This will require more study of the occurrence of Iowa coal.

The outcome of geologic studies on the continuity of Iowa coal deposits will have a marked effect on the establishment of mine site generating plants in Iowa. If a single deposit of sufficient size is found, mine site power generation will be feasible. If a group of discontinuous deposits at the same horizon and which when combined provide a sufficient total tonnage are located within a radius of a few miles of each other, mine site power generation operations could still be economically feasible. If the deposits are separated by distances on the order of 10-20 miles or more, such an operation will not be economic.

Regardless of the final result of extensive geologic study in Iowa of the Pennsylvanian system and its coal deposits, these data are essential if orderly, efficient planning is to be applied over the medium and long runs by the coal industry and the electric utilities. The bituminous coal industry must be prepared in advance to adapt to conditions, both economic and technological, expected to prevail in the future if it is to continue operating and if it is to reverse its decline. The industry can no longer afford to sit back and take whatever comes as it has in the past.

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APPENDIX A. GLOSSARY OF TERMS

British Thermal Unit (BTU). The quantity of heat required to raise the temperature of one pound of water one degree Fahrenheit at or near its point of maximum density (about 39^{o} F.).

Core. A cylinder of rock much longer than its diameter obtained by rotary drilling.

Core Sample. See core.

Coring. The process of drilling to obtain a core sample.

Cyclothem. A repeated sequence of sedimentary rock types (lithologies) resulting from cyclical deposition of sediment under marine, then non-marine, and back to marine conditions. Coal often occurs in the non-marine deposits (non-marine facies).

Dolomite. A carbonate rock made of grains of the mineral dolomite ($CaCO_3 \cdot MgCO_3$).

Economy of Location. In economics, the economies in terms of time and money which can be achieved by purposely locating a business near to a market, near to a source of natural resources used in the business, near to a transportation access, in an area where taxes are low, or for some other advantageous characteristic of the site.

Economy of Scale. In economics, the economies in terms of time and money which can be achieved on a per unit of output basis when the number of units produced is increased. For example, a mine producing 10,000 tons of coal per year might have production costs of $2.50 per ton, while a mine producing 1,000,000 tons per year might have production costs of $2.00 per ton.

Facies. A stratigraphic body as distinguished from other bodies of different appearance or composition.

Lenticular. Shaped like a double convex lens, i.e., thin at the edges and thick at the center.

Limestone. A carbonate rock made of grains of the mineral calcite ($CaCO_3$).

Marcasite. A sulfide mineral having the same composition as the mineral pyrite (FeS_2), but with a different crystal form. See pyrite.

Market. In economics, the entity (a single purchaser or a group of purchasers) which purchases a particular good or service. The overall market can be subdivided into smaller markets, each of which purchases the good or service for a particular use.

Ore Skip. The container (similar to an open-topped elevator cage) in which ore is hoisted from a subsurface mine level to the surface.

Overburden. In mining, the consolidated or unconsolidated material overlying an orebody.

Pyrite. A sulfide mineral having the composition FeS_2 (iron and sulfur). It is commonly known as fool's gold due to its yellowish color.

Rotary drilling. A method of drilling in which the entire drill pipe is rotated in the hole, thus rotating the cutting bit affixed to the end of the pipe and cutting the rock. Cuttings are removed by liquid flowing down the inside of the hollow drill pipe and returning to the surface between the drill pipe and the wall of the hole.

Sandstone. Solid material which is being transported in liquid suspension or which has settled from a liquid suspension.

Shale. A rock type composed of fine-grained (clay-size), non-carbonate sediment. Shale is commonly laminated.

Skip. See Ore Skip.

Underclay. A stratum of clay beneath a coal bed, often containing roots of coal plants. Also called "fireclay".

APPENDIX B. MINING LAW

Important Excerpts From Iowa Surface Mine Land Rehabilitation Statutes

Source: Iowa Senate File 279, effective January 1, 1968

Sec. 17. Every operator authorized under this Act to engage in surface mining on a site where mining operations disturb overburden containing acid-forming materials shall, when feasible, avoid placing on the surfaces of spoil banks any materials likely to form acid in amounts which will prevent or impede establishment of desirable vegetation on the spoil banks. After completion of mining operations the operator shall within the time specified in section nineteen (19) of this Act:

1. Grade irregular spoil banks to reduce peaks and ridges to a rolling topography suitable for establishment of desirable vegetation by striking off ridges and peaks to a width of at least twenty-four (24) feet at the top.

2. Grade spoil banks other than irregular spoil banks to slopes having a maximum of one (1) foot of vertical rise for each three (3) feet of horizontal distance except that where the original topography of the affected land was steeper than one (1) foot of vertical rise for each three (3) feet of horizontal distance, the spoil bank shall be graded to blend with the surrounding terrain.

3. Construct an earth dam in the final cut at any site where a lake or pond may be formed if necessary to properly control drainage from the site and if formation of a lake will not interfere with underground or other mining operations or damage adjoining property.

4. Cover, with at least two (2) feet of earth or spoil material, acid-forming materials present in a mineral seam exposed by mining operations if the exposed acid-forming materials are not covered by impounded water.

A bond or security posted under this Act to assure rehabilitation of land affected by surface mining shall not be released until all rehabilitation work required by this section has been performed to the department's satisfaction, except when a replacement bond or security is posted by a new operator under section sixteen (16) of this Act.

Sec. 19 An operator of a surface mine shall rehabilitate land affected by surface mining within twenty-four (24) months after the filing of a report required under section eighteen (18) of this Act indicating the mining of any part of a site has been completed. (Ed., remainder of section omitted).

Note: The remainder of the file is concerned with procedural matters and definitions of terms.

APPENDIX C. COAL QUALITY

Table 6. Summary of analyses of Iowa coals arranged by county[a]

County	# of analyses averaged	Moisture as received	Volatile matter	Fixed carbon	Ash	Sulfur	BTU as received	BTU dry	Ash-softening temperature, °F.	Agglomerating index	Free-swelling index	Hardgrove grindability index
Appanoose	52	16.3	35.4	37.1	12.4	4.4	10,014	14,166	1,968	Cf	3.0	55
Boone	7	17.8	33.2	35.4	13.7	5.9	9,509	14,330	2,107	--	---	--
Dallas	13	16.6	32.7	37.0	13.7	4.2	9,756	14,452	2,077	--	---	--
Davis	1	12.2	42.5	38.5	19.0	8.6	9,910	11,380	1,920	Cf	3.0	59
Jasper	3	16.3	37.9	38.2	16.1	5.5	9,618	12,878	2,013	Cf	---	--
Lucas	22	18.0	34.9	38.3	14.7	4.0	9,612	13,671	2,060	--	3.0	63
Mahaska	12	14.6	40.0	39.2	15.3	3.7	10,259	12,115	2,008	Cf	3.3	64
Marion	97	17.2	36.2	37.4	14.2	5.2	9,693	13,431	2,014	Cf	2.7	64
Monroe	30	15.1	38.2	37.7	13.2	4.2	10,165	13,708	1.998	Cf	3.3	61
Page	6	20.5	34.7	35.0	9.8	3.4	9,640	14,000	2,256	--	---	--
Polk	23	13.8	33.7	35.0	17.4	5.4	9,676	14,175	2,018	--	---	--
Taylor	2	11.8	37.2	36.7	14.3	6.5	10,420	14,590	2,080	--	---	--
Wapello	9	15.5	38.5	36.7	13.1	5.1	10,138	13,839	2,078	Cf	4.0	57
Warren	11	11.9	36.8	38.2	13.3	4.4	10,649	--	--	--	---	--
Wayne	1	18.7	34.6	36.0	10.7	4.9	9,830	14,300	1,930	--	---	--
Webster	7	22.2	34.6	32.1	11.1	5.8	9,083	--	2,158	--	---	--
VanBuren	2	11.8	37.2	36.7	14.3	6.5	10,420	14,590	2,080	--	---	--

[a]Data source: Reference Nos. 1-12 and No. 35.

Table 7. Summary of analyses of Iowa coals arranged by identified bed[a]

Bed name[b]	# of analyses averaged	Moisture as received	Volatile matter	Fixed carbon	Ash	Sulfur	BTU as received	BTU dry	Ash-softening temperature, °F.	Agglomerating index	Free-swelling index	Hardgrove grindability index
Mystic	53	16.3	35.4	37.1	12.4	4.4	10,011	14,169	1,967	Cf	3.0	55
Blackjack	7	17.8	33.2	35.4	13.7	5.9	9,509	14,330	2,107	--	---	--
No. 3	13	15.5	34.4	35.5	13.8	4.9	9,925	14,463	2,057	Cf	---	--
Cherokee	12	15.4	40.3	41.5	18.2	6.0	9,621	11,359	2,024	Cf	2.5	65
Des Moines #1	3	19.1	41.8	42.9	15.3	6.2	9,420	11,657	2,010	Cf	2.5	65
No. 5	6	12.4	33.5	39.8	14.3	2.5	10,428	--	--	--	---	--
Smoky Hollow	7	17.6	42.4	43.1	14.5	5.3	9,986	11,950	2,040	Cf	3.5	63
Mammoth	1	17.5	41.9	42.0	16.1	2.9	9,660	11,710	1,980	Cf	3.0	58
Nodaway	10	20.5	33.4	35.2	10.9	3.7	9,486	14,078	2,227	--	---	--
Kirkville	3	14.9	37.4	33.2	14.5	5.7	9,957	14,265	1,957	--	---	--

[a]Data source: Reference Nos. 1-12 and No. 35.

[b]Note that bed names are not necessarily stratigraphic names, as many of the beds have not been geologically correlated, and have been named for convenience only by the miners.

APPENDIX D. COAL FREIGHT-RATE STRUCTURE

Illustrative Examples Excerpted from Iowa Commodity Tariff 160-S, Iowa Commerce Commission A-4403, Effective 12/25/61, Governing Rail Transportation (Reference No. 54)

Column A rates apply on lump and nut bituminous coal.
Column B rates apply on pea and slack coal (coal which has been passed through a bar screen not exceeding one and one-half inches between bars, or its equivalent, a two inch mesh or a two inch round perforation).

General rates --

Rates in cents per 2,000 pounds

Distance of (miles)	Column A	Column B	Distance of (miles)	Column A	Column B
5	119	110	160	287	264
10	119	110	170	294	270
15	119	110	180	298	276
20	126	118	190	302	280
25	134	124	200	308	285
30	141	131	210	312	290
35	148	137	220	316	295
40	154	142	230	321	299
45	161	147	240	326	302
50	166	153	250	331	308
55	187	157	260	335	311
60	192	163	270	339	315
65	199	169	280	345	320
70	205	189	290	349	323
75	210	193	300	360	328
80	216	199	320	369	336
85	222	205	340	378	345
90	228	210	360	387	360
95	233	214	380	397	369
100	241	220	400	405	378
110	248	228	420	415	387
120	258	236	440	424	397
130	266	244	460	434	405
140	274	250	480	442	415
150	283	260	500	452	424

Specific commodity rates (point-to-point) --

By cheapest route to Des Moines from:	Column A	Column B	Approx. track miles	Approx. ¢/ton-mile(B)
Albia	123	85	62	1.4
Beacon	123	85	53	1.6
Bussey	---	85	50	1.7
Centerville	123	145	86	1.7
Chariton	123	85	49	1.7
Dunreath	123	85	--	---
Durham	123	85	--	---
Knoxville	123	85	34	2.5
Eddyville	123	85	63	1.4
Evans	123	85	50	1.7
Melcher	123	85	32	2.7
Monroe	123	85	29	3.0
Otley	123	85	33	2.6
Williamson (Mines No. 4 and 5)	123	85	42	2.0
Eldon	160	145	87	1.7
Flagler	123	85	38	2.2
Floris	139	126	93	1.4
Givin	123	85	56	1.5
Oskaloosa	123	85	53	1.6
Hamilton	123	85	52	2.6
Harvey	123	85	43	2.0
Tracy	123	85	47	1.8
Kirkville	127	89	68	1.3
Lovilia	123	85	56	1.5
Ottumwa	139	126	75	1.7
Williamson	123	110	42	2.6

Comparison of general and specific rates to Des Moines for pea and slack coal -- (approximated)

Distance	¢ per ton-mile General	¢ per ton-mile Specific	% reduction over general rate
20	5.9	4.5	26
25	5.0	3.4	32
30	4.4	2.9	34
35	3.9	2.4	39
40	3.6	2.1	42
45	3.3	1.9	43
50	3.1	1.7	45
55	2.9	1.5	48
60	2.7	1.4	48
65	2.6	1.3	50
70	2.7	1.3	52
75	2.6	1.3	50
80	2.5	1.3	48
85	2.4	1.3	46
90	2.3	1.3	40