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OF THE

UNITED STATES GEOLOGICAL SURVEY

TO THE

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CONTENTS.

THE COAL FIELDS OF THE UNITED STATES

BY

CHARLES WILLARD HAYES

CONTENTS.

ILLUSTRATION.

THE COAL FIELDS OF THE UNITED STATES.

By C. W. Hayes.

INTRODUCTION.

Many requests reach the office of the Geological Survey for information concerning the coal supply of various portions of the United States. This information, so far as published, is at present scattered through technical and scientific journals and Government reports, and is in many cases practically inaccessible to those most interested. To answer these inquiries there has been prepared a series of papers which are intended to summarize all practical information now available concerning the coal fields of the United States. In the description of the various fields the classification adopted is based on geographic, geologic, and trade relations. The titles and authors of the papers forming the series are as follows:

1. The Atlantic coast Triassic coal field (Virginia and North Carolina), by Jay Backus Woodworth.
2. The Pennsylvania anthracite coal field, by H. H. Stoek.
3. The Northern Appalachian coal field (Pennsylvania, Ohio, Maryland, West Virginia, Virginia, and eastern Kentucky): Pennsylvania and Maryland, by David White; Ohio, by Robert M. Haseltine.
4. The Southern Appalachian coal field (Tennessee, Georgia, and Alabama), by Charles Willard Hayes.
5. The Eastern Interior coal field (Indiana, Illinois, and western Kentucky), by George H. Ashley.
6. The Northern Interior coal field (Michigan), by Alfred C. Lane.
7. The Western Interior coal field (Iowa, Nebraska, Missouri, and Kansas), by Harry Foster Bain.
8. The Southwestern coal field (Arkansas, Indian Territory, and northern Texas), by Joseph A. Taff.
9. The Rocky Mountain coal fields (Montana, North Dakota, South Dakota, Wyoming, Utah, Colorado, and New Mexico), by L. S. Storrs.
10. The Pacific coast coal fields (Washington, Oregon, and California), by George Otis Smith.
11. The coal resources of Alaska, by Alfred Hulse Brooks.

Each author is personally familiar with the field he describes, so that the papers contain much matter hitherto unpublished. This is especially true of the less well known fields, such as those of the

Rocky Mountain region and Alaska. The papers are, however, primarily summaries of existing information, and all reliable sources have been freely utilized in their preparation. A special effort has been made to obtain the latest and most accurate statistics possible, and much valuable information has been procured by means of a schedule of inquiry sent out to coal operators, a large majority of whom returned full replies.

In order to secure proper coordination among the reports on the several fields and uniform arrangement of the material, an outline was submitted to the various authors as a guide in the preparation of the papers, which has been conformed to as nearly as the diverse conditions prevailing in different fields would permit. The state of development naturally determined whether greater attention should be paid to the geologic or the commercial phase of the subject. The former aspect has been emphasized in the little-known fields, as in Alaska, where the immediate need is for information to aid the prospector, while the chief attention has been paid to the latter in a thoroughly developed field, like the Pennsylvania anthracite.

DISTRIBUTION OF COAL IN THE UNITED STATES.

Coal occurs in commercial quantities in 27 of the 47 States and Territories of the United States and in Alaska. The following table shows the areas of coal-bearing formations in the several States and the rank of the coal-producing States in area and production:

Rank of coal fields and coal-producing States in area and production.

Coal field, and State or Territory.	Area of coal-bearing formations.	Per cent probably productive.	Rank of field and State in area.	1900. Production.	Average price per ton.	Per cent of total production.	Rank in production.
Anthracite field:	Sq. miles.						
Colorado and New Mexico				98,404		0.04	
Pennsylvania	484		26	57,367,915	$1.40	21.25	1
			X				
Atlantic coast Triassic:							
Virginia	270	50	30	57,912	1.79	0.02	
North Carolina	800	(?)	24				
Total	1,070		VIII	57,912			
Northern Appalachian:							
Pennsylvania	15,800	75	7	79,842,326	.97	29.58	1
Ohio	12,000	70	10	18,988,150	1.02	7.03	4
Maryland	510	80	25	4,024,688	.98	1.49	11
Virginia	1,850	80	22	2,353,576	.89	.87	17
West Virginia	17,280	75	6	22,647,207	.81	8.39	3
Kentucky (east)	10,300	70	13	2,222,867	.92	.82	18
Total	57,740		III	130,078,814			

Rank of coal fields and coal-producing States in area and production—Continued.

Coal field, and State or Territory.	Area of coal-bearing formations.	Per cent probably productive.	Rank of field and State in area.	1900.			
				Production.	Average price per ton.	Per cent of total production.	Rank in production.
Southern Appalachian:	*Sq. miles.*						
Tennessee	4,400	47	18	3,708,562	$1.14	1.38	13
Georgia	167	14	31	315,557	1.17	.12	26
Alabama	8,500	44	15	8,394,275	1.17	3.11	5
Total	13,067	....	VI	12,418,394	....	....	......
Northern Interior:							
Michigan	11,300	(?)	12	849,475	1.48	.31	25
	....	....	VII	....	....	....	......
Eastern Interior:							
Indiana	9,300	60	13	6,484,086	1.03	2.40	6
Illinois	42,900	50	1	25,767,981	1.04	9.55	2
Kentucky (western)	5,800	65	17	3,106,097	.92	1.15	15
Total	58,000	....	II	35,358,164	....	....	......
Western Interior:							
Iowa	20,000	50	4	5,202,939	1.38	1.93	9
Missouri	23,000	60	2	3,540,103	1.21	1.31	14
Nebraska	3,200	....	19	....	....	....	......
Kansas	20,000	75	3	4,467,870	1.22	1.65	10
Total	66,200	....	I	13,210,912	....	....	......
Southwestern:							
Indian Territory	14,848	50	8	1,922,298	1.45	.71	19
Arkansas	1,728	75	23	1,447,945	1.14	.54	21
Texas	11,300	45	11	968,373	1.63	.36	24
Total	27,876	....	V	4,338,616	....	....	......
Rocky Mountain:							
South Dakota	120	....	32	129,883	1.22	.05	28
Montana	13,000	....	9	1,661,775	1.63	.62	20
Idaho	....	....	....	10	5.00	....	30
Wyoming	7,500	50	16	4,014,602	1.36	1.49	12
Utah	2,000	30	21	1,147,027	1.26	.42	23
Colorado	18,100	50	5	5,182,176	1.12	1.92	8
New Mexico	2,890	40	20	1,263,083	1.37	.47	22
Total	43,610	....	IV	13,398,556	....	....	......
Pacific coast:							
Washington	450	....	27	2,474,093	1.90	.92	16
Oregon	320	....	28	58,864	3.74	.02	29
California	280	....	28	171,708	3.05	.07	27
Total	1,050	....	IX	2,704,665	....	....	......

Areas of lignite-bearing formations are not included in the above table, although they are shown on the accompanying map (Pl. I). These areas are extensive and their beds of lignite contain a vast reserve of valuable fuel, but they are not strictly comparable with the higher grade fuels of the anthracite and bituminous fields. There are approximately 56,500 square miles of lignite-bearing formations, chiefly

Cretaceous, in Montana, the Dakotas, and Wyoming. The Tertiary lignite-bearing formations of Alabama, Mississippi, Louisiana, Arkansas, and Texas constitute another area of about equal extent. The percentage of the areas of coal-bearing formations which is probably productive is fairly well known in a few of the thoroughly developed fields. In most of the fields, however, the figure given is merely an estimate based on incomplete data, while in a few the available data are of such a character that an estimate would have little if any value. The estimates given are believed to be conservative in every case. It should further be remembered that large areas which under present conditions are, for various reasons, classed as unproductive, may in the future, under changed conditions, become productive. This is the case with those fields in which the coal lies too deep to be mined with profit at the present time.

The true rank of the several coal fields and States in value of the available fuel which they contain is not indicated by the table, since area of coal-bearing formations and percentage of productive area are only two of the factors which determine that value. Other factors are the number and thickness of the workable beds of coal, its quality as fuel, and the ease with which it can be mined. The data are not at present available for bringing these factors into the problem.

It will be noted that the rank of the States in production is quite different from their rank in area of coal-bearing formations. Thus the Northern Appalachian field, which ranks third in area, ranks first in tonnage and value of product, while the Western Interior field, which ranks first in area, is fourth in production. This result is due to several causes, among the most important of which are (1) proximity to markets, (2) suitability of the coal to the fuel requirements, (3) relative quantity of workable coal per square mile of productive area.

GEOLOGIC RELATIONS OF THE COAL FIELDS.

The coal-bearing formations of the United States range in age from Carboniferous to Tertiary. The Carboniferous coals are confined to the region east of the one hundredth meridian, and the Triassic coals to the Atlantic coast. Most of the Cretaceous coal fields lie in the Rocky Mountain region, between the one hundredth and one hundred and fifteenth meridians, and the Tertiary coal fields are between the one hundred and twentieth meridian and the Pacific coast. During the three great coal-forming periods, therefore, the Carboniferous, the Cretaceous, and the Tertiary, there has been a successive westward shifting of the zone within which conditions favorable for the accumulation of coal prevailed. Exceptions to this westward progression of the coal-forming zone were the deposition of coal east of the Carboniferous fields in Triassic time and south of the Carboniferous fields during Tertiary time.

THE CARBONIFEROUS COAL FIELDS.

There are five main subdivisions of the Carboniferous coal fields, two of which are subdivided for convenience of treatment in the following series of papers. They may be briefly characterized as follows:

The anthracite field is confined to eastern Pennsylvania, and contains 484 square miles of productive area. It consists of several long, narrow, synclinal basins, whose axes are approximately parallel, extending in a northeast-southwest direction. They do not differ materially from the ordinary synclines of the sharply folded Appalachian belt, except that they are sufficiently deep to have preserved the Coal Measures, which have elsewhere throughout this folded belt been generally removed by erosion in the synclines as well as upon the anticlines. This field has been thoroughly developed, and a larger proportion of its coal has been mined than of any of the other fields. Estimates are given in the following paper of the amount of coal which the field contained before mining began and the amount now remaining. These estimates, based upon a large number of careful measurements, are probably fairly correct. Since the geologic conditions in the anthracite field are so well known, the paper by Mr. Stoek is devoted largely to its commercial aspects and to methods of mining and preparing the coal for market.

The Appalachian field, which has been subdivided into northern and southern fields, extends from the northern border of Pennsylvania southwestward 850 miles to central Alabama. It embraces portions of nine States, and contains, approximately, 70,800 square miles, of which about 75 per cent contains workable coal. The eastern margin of this field forms the western border of the sharply folded Appalachian belt, and along this margin the strata have suffered some folding, a few outlying synclines being nearly or quite separated from the main field by steep eroded anticlines. In general, however, the strata in this field are either gently undulating or essentially horizontal. The formations which make up the Coal Measures are generally thickest along the eastern margin of the field, thinning rapidly westward. In the same direction there is a corresponding decrease in number and thickness of the coal beds. These formations consist of overlapping lenses of conglomerate, sandstone, shale, coal, and occasionally limestone, none of which can be traced throughout the entire field. Some coal beds, as the Pittsburg and Sewanee, may be indentified over several thousand square miles, but more generally the workable coal is in local thickenings of beds that are elsewhere worthless. For this reason correlations of individual beds in distant parts of the field are of doubtful value, although particular horizons may often be closely correlated by means of the fossil plants they contain. Some portions of the field have been carefully prospected, chiefly those in which development has been most active, but large areas, particularly in West Virginia and Kentucky, remote from lines of transportation, remain practically unknown.

The Northern Interior field lies wholly within the State of Michigan and has an area of approximately 11,000 square miles. It forms an oval area whose outlines are imperfectly known, since the region is deeply covered by glacial drift. Prospecting is done entirely by means of the drill, and on account of the expense involved the proportion of the field underlain by workable coal can not at present be estimated. The strata appear to dip from the margins of the field toward its center, the formations thickening in the same direction. It is probable that this field was formed in an isolated basin and that its strata have never been continuous with those of the fields to the southeast and southwest, in Ohio and Indiana.

The Eastern Interior field embraces portions of Indiana, Illinois, and Kentucky, having an area of 58,000 square miles. It forms an oval basin whose longer axis extends northwest and southeast, nearly at right angles to the axis of the Appalachian field. The strata about the margins of the basin have gentle dips toward its center, while in the interior of the basin they are practically horizontal. The workable coal beds are confined to the lower portion of the Coal Measures, and hence reach the surface in a broad belt about the margins of the basin. The development of the field has been confined to this belt, although the coal beds are supposed to extend beneath the unproductive formations which occupy the surface in the central portion of the field. It is estimated that about 55 per cent of the area is productive under present conditions, and that a considerable proportion of the remainder will become productive when conditions render mining at greater depths profitable. The Eastern Interior field is separated from the fields on either side by broad, gentle anticlines, from which the Coal Measures, which may originally have been continuous, have been removed by erosion.

The Western Interior and Southwestern fields form a practically continuous belt of Coal Measure rocks extending from northern Iowa southwestward 880 miles to central Texas, and embrace an area of 94,000 square miles in Iowa, Missouri, Nebraska, Kansas, Indian Territory, Arkansas, and Texas. At the eastern margin of these fields the underlying older formations reach the surface, while along their western margin the Coal Measures pass beneath the Permian and other formations of the plains region.

In the Western Interior field and the northern portion of the Southwestern in Indian Territory, as well as in the portion lying in Texas, the strata are nearly horizontal, having a uniform gentle dip to the west. In that portion of the field which lies in Arkansas and extends westward through the central part of Indian Territory the strata are somewhat sharply folded. This belt forms the northern border of the intensely folded and faulted Ouachita Mountain zone, whose structure corresponds closely with that of the Appalachians.

THE TRIASSIC COAL FIELDS.

Several small basins of Triassic rocks in the Piedmont region of Virginia and North Carolina are coal bearing. They contain an aggregate area of about 1,000 square miles. The most important of these, and the only ones at present productive, are the Richmond and Deep River areas. The strata of these basins rest directly upon the crystalline rocks of the Piedmont Plateau. They may originally have been continuous and nearly horizontal, but are now separated and considerably folded and faulted. They have also been invaded by dikes and sheets of igneous rocks, which have at some points converted the coal into natural coke or carbonite. While the coal is in some places of excellent quality, it shows great irregularity, as would be expected from the conditions under which it was deposited and the movements to which it has subsequently been subjected. These fields are chiefly of historic interest, since the first systematic coal mining in the United States was carried on within their borders.

THE CRETACEOUS COAL FIELDS.

As conditions had been favorable for the accumulation of coal in the region east of the one hundredth meridian during Carboniferous time, so they were favorable for its accumulation during Cretaceous time in the region between the one hundredth and one hundred and fifteenth meridians. Since the deposition of the Cretaceous formations in this region it has been subjected to the action of mountain-building forces and to intense volcanic activity. Hence the coal-bearing formations, which may originally have been continuous over much of this region, occur in small, irregular basins separated by larger areas of elevation and erosion or by areas of igneous rocks. Although the folding of the strata and their invasion by igneous rocks have greatly reduced the area of the coal-bearing formations, the quality of the coal has been thereby greatly improved. In the extensive undisturbed Cretaceous areas which extend eastward from the Rocky Mountains beneath the plains region in Montana, Wyoming, and the Dakotas, there are numerous beds of lignite, while the same horizons on the flanks of the mountains yield high-grade bituminous coal.

The Cretaceous coal fields are included within a belt that extends from the Canadian boundary southeastward for a distance of 1,200 miles. Its axis coincides with the main range of the Rocky Mountains, but includes also numerous outlying ranges. Its greatest breadth is about 500 miles. It embraces portions of Montana, South Dakota, Wyoming, Colorado, Utah, and New Mexico. Mr. Storrs has described 45 separate areas within this belt, having an aggregate extent of 43,610 square miles. All of these areas are known to contain workable coal, but many of them are undeveloped and practically unexplored, so that estimates of the productive area are not by any means exact.

Two small areas of Cretaceous coal-bearing formations in western Texas are not described in Mr. Storrs's paper, although they properly belong with the Rocky Mountain fields. The westernmost of these is the San Carlos coal field, in El Paso County. Considerable outlay has been made here in development, but all the coal thus far discovered is a low-grade fuel, and the field is not now producing. The Eagle Pass field is much the larger and more important of the two, and contains some coal of excellent quality. It extends from the northern border of Uvalde County about 75 miles southwestward to the Rio Grande, and beyond the international boundary expands to a broad area in Mexico. The strata have been considerably disturbed, and probably only a small proportion of the field will prove to be productive.

Practically all the available information concerning these Texas Cretaceous coal fields is contained in a report by T. Wayland Vaughan, entitled Reconnaissance in the Rio Grande coal fields of Texas: Bull. U. S. Geol. Survey No. 164, 1900.

THE TERTIARY COAL FIELDS.

The Tertiary formations in various parts of the United States contain a large amount of vegetable organic matter which, in many places, forms beds of lignite. In a few places near the Pacific coast conditions have been favorable for the conversion of this lignite into true coal. The most important deposits of this Tertiary coal are in Washington. Here the folding of the inclosing strata and the intrusion of igneous rocks have converted the lignite into coal of fair quality. Similar conditions have prevailed at a few points in the extreme western portion of Oregon and in central and southern California. The productive fields are all small and have a total area of about 1,000 square miles. How much of this is productive has not yet been determined, even approximately, except in a few of the most thoroughly developed basins. As in the Rocky Mountain Cretaceous fields, the coal beds show great variability in thickness and character, and mining is attended by considerable difficulty, owing to the disturbed condition of the strata.

In addition to the coal-bearing Tertiary areas of the Pacific coast large areas of Tertiary formations occur in the southern portion of the United States which contain extensive beds of lignite. These Tertiary lignites are not described in any of the following papers, although they contain a large amount of fuel which will doubtless some time be utilized. Beginning at the Georgia-Alabama line a narrow belt of lignite-bearing formations extends westward nearly to the Mississippi River. West of the Mississippi the same formations occupy a much broader belt, extending from Little Rock southwestward through Arkansas, Louisiana, and Texas. The boundaries of these areas are quite indefinite, owing to the presence of later deposits, and probably only a small proportion of the area contains lignite beds of sufficient thickness and purity to be utilized. The outlines shown on the map merely indicate the areas within which, according to the best available information, beds of possible commercial value may be found.

CLASSIFICATION OF THE COAL AS FUEL.

The various fuel requirements call for coals of varying composition, and the adaptability of any coal to a particular purpose is determined largely by the relative abundance of the several fuel constituents. These consist of the volatile hydrocarbons and of the nonvolatile or fixed carbon. This relation is expressed by the *fuel ratio*, a quantity obtained by dividing the percentage of fixed carbon by the percentage of the volatile combustible constituents of the coal. In general the fuel value or heating power increases with the increase of the fuel ratio, since more heat is developed in the combustion of carbon than of the hydrocarbon compounds. This increase in fuel value, however, continues only to a certain point, beyond which the difficulty of effecting combustion more than makes up for the greater amount of heat evolved. Thus the graphitic anthracite of the Rhode Island field can not properly be regarded as a fuel, since the percentage of volatile constituents is so small that these have to be supplied by the addition of another coal before it will burn.

In addition to its fuel constituents a coal contains others which are nonessential. The most important of these are water and ash. The former not only replaces an equal weight of combustible matter but also absorbs heat in its volatilization. An excessive amount of water therefore detracts seriously from the fuel value of a coal. Its presence is further detrimental in causing the coal to break up into fine particles as it dries out. The amount of water generally varies inversely as the fuel ratio, being less than 1 per cent in some anthracites and from 15 to 25 per cent in lignites.

The ash simply occupies the place of combustible matter and is in general purely negative in its influence on the fuel. When very abundant it may seriously retard combustion, and when it contains easily fusible constituents it may become a positive detriment by forming clinker on the grate bars. Sulphur is detrimental in a steaming fuel chiefly by reason of the corrosive effect that its products of combustion exert on iron surfaces with which they come in contact.

For most metallurgical purposes it is essential that the coal should be relatively free from certain injurious constituents, such as sulphur and phosphorus.

The amounts of water and ash which a coal contains are not shown by its fuel ratio, and hence this does not serve to indicate its fuel value so much as its adaptability for specific purposes. Thus it is evident that for gas-producing purposes a coal should be chosen having a large proportion of volatile constituents; in other words, a low fuel ratio.

The coking quality of a coal depends on conditions which are in a measure independent of its chemical composition, although coking coals do not have a very wide range in fuel ratios, which generally fall between 1.20 and 2.50. By no means all coals will coke, however, whose ratios fall between these limits.

The coals of the Carboniferous fields considered as a whole show a decrease in their fuel ratios from east to west. In the Rhode Island field the coal has suffered so high a degree of metamorphism that it has passed the anthracite stage and has been partially converted into graphite, practically all the volatile compounds having been driven off. The Pennsylvania anthracite has fuel ratios varying within rather wide limits. In the analyses accompanying Mr. Stoek's paper the maximum is 27 and the minimum 5.11, though most of the samples analyzed fall between 9 and 22, the average of 16 analyses being 14.11.

Within a narrow belt along the eastern margin of the northern Appalachian field the coal is relatively hard and high in carbon, forming an intermediate variety between the true anthracite on the east and the true bituminous on the west. The fuel ratios within this belt are generally between 3 and 5.

In the greater part of the Appalachian field the coals have fuel ratios ranging from 1 to 3, and as a rule the ratios are higher in the northern and eastern portions of the field as compared with the southern and western portions. There are, however, many exceptions to this rule.

The field presents certain well-marked types of coal which for particular purposes are regarded as the standard fuels. Thus the coal of the Pittsburg bed, in the Connellsville district, is usually taken as the standard with which other coking coals are compared. In the same way the Pocahontas coal may be considered a standard steaming fuel. Small areas occur in this field containing special varieties of coal, such as splint, cannel, block, etc., which are particularly well suited for certain purposes—as gas-making, domestic, and locomotive fuel.

The Northern Interior field contains only bituminous coal, which forms a fair steaming fuel, though it is inferior to most of the Appalachian coals. It generally contains a high percentage of ash and sulphur. Its fuel ratios vary from about 1.13 to 1.63, the average of 8 representative analyses given in the accompanying paper being 1.40.

Three varieties of coal occur in the Eastern Interior field. By far the largest part of the coal mined is soft bituminous, making a good steam fuel. In a belt along the eastern margins of the field in Indiana is a variety known as block coal, which differs from the ordinary bituminous in its physical characteristics rather than in chemical composition. It is especially well adapted for domestic fuel. In the Kentucky portion of the field are numerous small areas of cannel coal, particularly valuable for gas-making and domestic purposes. The means of the fuel ratios obtained from a large number are as follows: For Indiana coals, 1.30; Kentucky, 1.57, and Illinois, 1.71.

The coal of the Western Interior field is fairly uniform in composition, having an average fuel ratio of about 1.30 and forming a fair steaming fuel. In the Southwestern field considerable more diversity is found, the coal varying from soft bituminous, with a fuel ratio of 1.14 in northern Texas, to a semianthracite in Arkansas with a fuel ratio of nearly 9. The range in character of the coals in this field is shown in the accompanying table:

Table showing fuel ratios of coals in the Southwestern field.

	Number of analyses.	Minimum fuel ratio.	Maximum fuel ratio.	Mean fuel ratio.
Arkansas:				
Semianthracite	27	....	8.96	5.79
Semibituminous		5.04	7.62	
Bituminous		3.51	4.99	
Indian Territory:				
Bituminous	24	1.26	5.22	2.68
North Texas:				
Bituminous	7	1.14	1.79	1.45

The Atlantic coast Triassic coal closely resembles the Carboniferous coals of the Appalachian field, but is generally higher in ash and sulphur. In the Richmond area the fuel ratios range from 1.8 to 3.4, the average of 7 analyses given by Mr. Woodworth being 2.4. In the Deep River area they range from 1.6 to 3, the average of 17 analyses being 2.11.

In the Rocky Mountain and Pacific fields the coal presents very great diversity in character, the same basin sometimes containing all the intermediate varieties between lignite, with a fuel ratio less than 1, and anthracite with a ratio of 20 or more. These abrupt changes in chemical composition and physical properties are due to the varying degrees of alteration which the coal has undergone. The alteration is produced by the pressure due to the weight of overlying strata or to the folding of the strata by mountain-building forces and by the metamorphism of intrusive igneous rocks. The first of these agencies, vertical pressure, is least effective, but most widespread in its effects; the second, lateral pressure, is more effective and relatively local, while the third, intrusion, produces effects which are extremely localized and correspondingly intense. As a result of these conditions the coal of the plains region is largely lignite, although the lowest beds, those which have been most deeply buried, approach most nearly to true coal. Along the flanks of the mountains and in the interior basins, where the inclosing strata have been moderately folded, the coal is chiefly bituminous. In the same regions more intense folding and the intrusion of igneous rocks have converted the bituminous coal into semibituminous or anthracite.

DEVELOPMENT, PRODUCTION, AND MARKETS.

The first development of the several coal fields of the United States has been in response to the fuel demands of adjoining regions, while an abundant fuel supply has determined the location of many industrial establishments, which have in turn greatly increased the demand. The tonnage of coal produced in the various coal fields, as shown in the accompanying table, is not proportional to their area, but depends upon other conditions, such as transportation facilities, extent of markets, and character of the fuel. The largest output in proportion to area is in the Pennsylvania anthracite field, where 118,528 tons were produced in 1890 for each square mile of productive area. This large output is due to the superiority of anthracite as a domestic and locomotive fuel and the density of the population in regions adjacent to this field. The distribution of the anthracite product to the various States and the extent to which it competes with the product of other fields are shown in Mr. Stoek's paper.

Owing to its location and the excellent character of its coal, the Northern Appalachian field controls the market for bituminous coal in the Eastern States, coming in competition in the northeastern portion of this territory only with the Nova Scotian field. It is the nearest of the large bituminous fields to the seaboard, and will therefore supply a large proportion of the coal which must be mined to meet the growing demands of the export trade. Its coal reaches the seaports between New York and Norfolk by a number of direct railroad lines, the most important of which are the Pennsylvania, Baltimore and Ohio, Chesapeake and Ohio, and Norfolk and Western.

The Southern Appalachian field supplies the South Atlantic and Gulf States as far west as the Mississippi. Its southern portion is almost as near the seaboard as the northern Appalachian field, and it will in time support a large export trade, particularly to Central and South American ports, and on the completion of an isthmian canal to Pacific coast ports also.

Appalachian coal has an outlet to the West by way of the Great Lakes, the Ohio River, and numerous trunk-line railroads. Lake transportation is interrupted in winter, but during the summer season the Northern Appalachian field supplies most of the markets on the Great Lakes, competing with the nearer Northern and Eastern Interior fields. By means of the Ohio River the Northern Appalachian field supplies adjacent portions of Ohio, Kentucky, and Indiana, as well as markets along the Lower Mississippi, where it competes with the Southern Appalachian field.

The markets for the coal of the Northern Interior field are chiefly within the field itself and in the immediately adjoining region. A small amount finds a market in the northern peninsula of Michigan and in Wisconsin. The coal of this field is inferior to that of Pennsylvania and Ohio, and can compete with the latter only when it has a decided advantage in the matter of freights.

The markets of the Eastern Interior field are also chiefly within its own limits and in immediately adjacent regions. It supplies the Chicago market in part and also some territory to the northwest and southwest. It occupies a central position among the Carboniferous coal fields, and its product comes in competition with that from all the others. It supplies the markets westward to the margin of the Western Interior field, but goes eastward only a short distance into the region which separates it from the Appalachian field, where it competes not only with the better coal from the latter field but also with the cheap fuel supplied by the natural gas fields of Ohio, Indiana, and Kentucky.

The Western Interior field supplies the markets within its own borders and toward the north and west, where it comes in competition with the Rocky Mountain fields.

The Southwestern field supplies the markets in a large territory toward the south and west, in which it has little competition. Practically all the fuel used by the Southern transcontinental railroads, as well as the Texas roads, comes from the north Texas and Indian Territory fields. The hard coals of the Arkansas field supply an extensive region west of the Mississippi River with a high-grade domestic fuel, which bears a relation to the neighboring soft coals somewhat similar to that borne by the Pennsylvania anthracite to the Appalachian bituminous coals.

Considering the entire region between the Appalachian coal field and the Rocky Mountain fields, there is observed a general westward movement of the coal. Thus the product of the Western Interior field goes west almost exclusively, that of the Eastern Interior field goes west to and within the borders of the Western Interior field, while the Appalachian coal goes west across both the Eastern and Western Interior fields and beyond the territory of the latter, competing with the Rocky Mountain coals to some extent. This westward tendency is due chiefly to the higher grade of the Eastern coals, but in part also to the fact that railroad freight rates are generally lower westward than eastward; water transportation also favors the westward rather than the eastward movement of coal.

The region west of the one hundredth meridian, which constitutes about half the area of the United States exclusive of Alaska and the other outlying possessions, contains less than 20 per cent of the coal fields. The largest area entirely without coal lies between the Rocky Mountains and the Pacific coast. This, however, is a region in which the population is scanty, and the fuel requirements are consequently small. The Pacific coast markets are supplied chiefly by the Washington fields, though considerable coal comes from the Nanaimo district in British Columbia, and some also from England as ballast in grain vessels, and from Australia as a return cargo.

The development of the coal resources of Alaska is as yet in the experimental stage. A local fuel supply is of the greatest importance to this territory, and the present indications are that such a supply will be furnished by some of the fields now known or others not yet discovered. Practically all the information at present available concerning these Alaskan coal fields is summarized by Mr. Brooks in the accompanying paper, which should form an invaluable aid in future prospecting and development.

THE ATLANTIC COAST TRIASSIC COAL FIELD

BY

JAY BACKUS WOODWORTH

CONTENTS.

ILLUSTRATIONS.

THE ATLANTIC COAST TRIASSIC COAL FIELD.

By Jay Backus Woodworth.

INTRODUCTION.

The Triassic coal areas of the Atlantic coast are included in the southernmost of a number of isolated trough-shaped basins of conglomerate, sandstone, and shale, with intrusions and occasional buried flows of basic igneous rocks. The name Newark was given by Redfield to the beds of which these basins are composed, on account of their occurrence at Newark, N. J. The northernmost of the Newark areas borders the Bay of Fundy and the southernmost occurs in South Carolina. The area in Massachusutts and Connecticut and the elongate tract extending from Orange County, N. Y., through New Jersey, Pennsylvania, and Maryland, into northern Virginia, are not known to contain coal except in isolated films associated with the fossil remains of single plant stems, as in the sandstones near Belleville, N. J., and in the inch-thick layers at Phœnixville, Pa. This report, therefore, discusses only the southern coal-bearing areas lying within the States of Virginia and North Carolina.

GEOGRAPHIC RELATIONS.

These southern coal areas lie in the Piedmont district, midway between the Blue Ridge Mountains and the Atlantic Ocean. This is a region of little relief, easily traversed in any direction by roads and railways, and having on its eastern border ready access to tide water by means of the James and Cape Fear rivers.

The productive tracts occur in two well-marked belts in Virginia and North Carolina, with an intermediate tract in Virginia. These belts extend for about 250 miles in a southwesterly direction, over an area nearly 100 miles wide.

The eastern belt includes the Taylorsville and Richmond areas in Virginia, and the Deep River area in North Carolina. The western belt includes the Dan River area. Between them lies the Farmville area in Virginia. The areas in Virginia will first be described, then those in North Carolina.

TAYLORSVILLE AREA, VIRGINIA.

The Taylorsville area is unimportant and unpromising. It lies on the extreme eastern edge of the Piedmont district about 20 miles north of Richmond, Va. The beds are exposed in the vicinity of Taylorsville, a station on the Richmond, Fredericksburg and Potomac Railroad. Little is known of the stratigraphy of the area.

The width of the area is about 8 miles, its length approximately 10 miles in a northwest-southeast direction. It is estimated to have an extent of 60 square miles.

Coal, it is reported, has been found, but a shaft sunk upon the bed did not give sufficient promise to lead to its development.

RICHMOND AREA.[a]

The Richmond area is the most important of the Triassic coal fields. It has been the longest known and the most extensively worked.

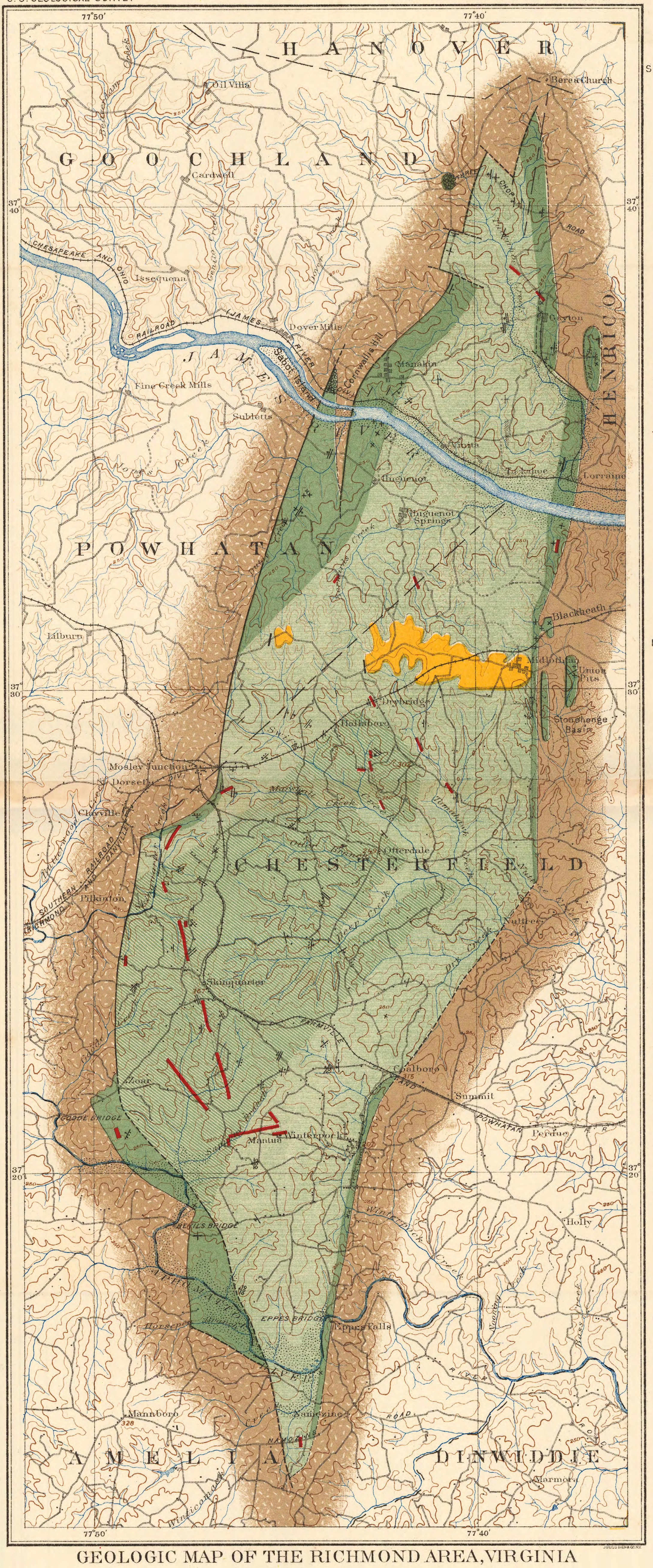
LOCATION AND BOUNDARIES.

The area is situated on the eastern margin of the Piedmont district, and its eastern outcrop is but 13 miles from the head of tide in the James River at Richmond. It lies in Goochland, Henrico, Powhatan, and Chesterfield counties, and extends about 31 miles north and south, beginning 9½ miles north of the James River and extending to and beyond the Appomattox on the south. Its greatest width is nearly 10 miles in the southern middle portion, from which it tapers toward either end. It has an area of approximately 150 square miles, the greater part of which is believed to be coal bearing, though the central portions are unexplored.

The eastern border, as shown on the map (Pl. II), is tolerably regular, with few offsets, and is readily traceable in the field. The western border is less regular and not so clearly shown.

The area has the form of a broad basin, along the eastern edge of which the coal horizon has been traced except where covered by alluvium in the Swift Creek drainage area. On the east of the main area north and south of the James River occur a few small outlying basins, now worked out. The Flat Branch or Springfield pits area lies east of Gayton; the Blackheath and Cunliff basins, and the Union pits and Stonehenge areas, lie east of Midlothian. The western margin of the field shows coal outcrops in the immediate vicinity of the James River. The largest developments have been on the eastern margin, at Gayton and Deep Run, north of the James, at Midlothian and the attendant basins south of that river, and in the southern portion of the basin at Winterpock (Clover Hill of the old reports). On the western margin the Manakin mines and the Old Dominion and Norwood workings have been the most prominent.

[a] Chesterfield coal field, Richmond deposit, Richmond coal field, of various authors.



GEOLOGIC MAP OF THE RICHMOND AREA, VIRGINIA

BY J. B. WOODWORTH, ASSISTANT GEOLOGIST

N. S. SHALER, GEOLOGIST IN CHARGE

Scale

0 1 2 3 4 5 MILES

Contour interval 50 feet

1898

GEOLOGIC RELATIONS.

AGE OF THE COAL-BEARING SERIES.

The coal-bearing rocks occur near the base of the Newark formation, and from their included plants have been in recent years held to be of Triassic age, in agreement with similar evidence from the other Newark areas.

The area is bordered on the east by coarse granites, which form the floor of the Triassic sediments on that side of the basin. About the northern and southern ends and along the western side of the area gneisses replace the granite and undoubtedly underlie the western half of the area. These rocks are presumably of Archean age and are readily distinguished from the coal-bearing strata.

STRATIGRAPHY.

The strata in the Richmond area have been recently grouped by Shaler and Woodworth in the following order, beginning at top:

Strata in the Richmond area.

	Feet.
Otterdale sandstones: Coarse sandstones, often feldspathic, with silicified trunks of Araucarioxylon and local lignite beds; developed about Otterdale in the southern and western parts of the area	500±
Vinita beds: Mainly black fissile shales with *Estheria ovata*, intercalated with grayish sandstones; exposed in the James River bluff and on Tomahawk Creek	2,000±
Productive coal measures: Interstratified beds of bituminous coal, usually three beds, with black *Estheria* shales, plant-bearing shales, sandstones	500±
Lower barren beds: Sandstones and shales, often largely arkose or granitic sandstones on eastern margin	0 to 300
Boscabel bowlder beds: Local deposits mainly seen on the western margin	0 to 50

These sediments are not well exposed, and the accompanying map (Pl. II) shows approximate boundaries only.

STRUCTURE.

The basin in the region of the James River has the general appearance of a broad, shallow syncline, with the beds dipping westward along the eastern margin, essentially flat with flexures downthrown to the west in the central part, and much broken but dipping mainly eastward on the western margin, where the coal-bearing rocks again rise to the surface. North and south of this river section the strata show evidence of faulting along the western margin by which the coal beds are thrown down at varying distances to different depths. Hence there is a general failure of the coal outcrop along the western margin. On the eastern margin, particularly toward the south, the westward-dipping strata have been deformed and have been forced into the form of north-south troughs. These are separated by arches, over the crests of which the coal beds are more or less completely pinched out.

Experience at the Winterpock mines has shown that by driving the slope downward and through one of these arches or "rolls," the coal is encountered on the opposite or lower side in approximately the same plane of descent.

A few borings made along the eastern margin confirm the evidence derived from mining that the dip carries the coal-bearing strata to a depth of 2,500 feet in the tract south of the James River at a distance of a mile from the eastern margin. Greater depths for the coal are indicated in the southwestern part of the field by the prevalent westerly dip in that district.

Detailed study of the structure of the basin has shown that the disturbances in the strata originated in the underlying granites and gneisses and that the strata are most broken and flexed in the lower beds, as shown in the old workings about the margins. It is to be expected, if this view be true, that disturbances will be encountered in the deeper beds of the central part of the area, notwithstanding the general flat position of the strata at the surface. There are indications

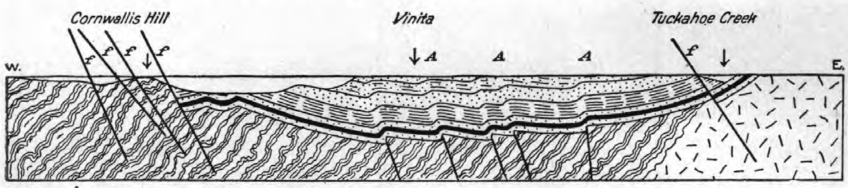
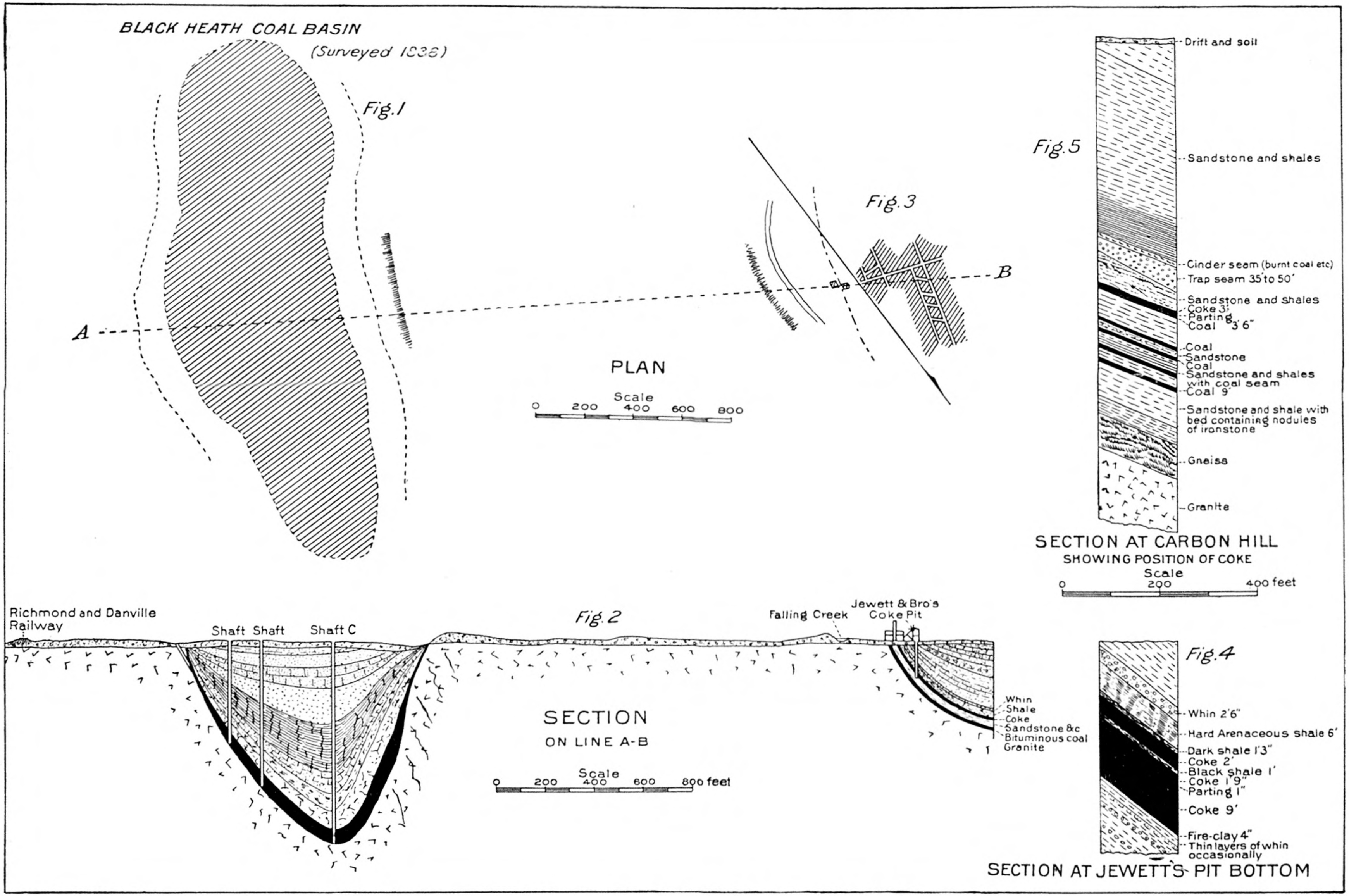


FIG. 1.—General structure section of the Richmond Basin in the vicinity of James River. *A, A, A,* minor flexures, with beds downthrown to the west; *f, f, f,* faults. The heavy black band represents the supposed position of the coal beds. North and south of this section the beds appear to be deeply faulted down against the western margin, and the apparent synclinal structure disappears. The superficial portion of this section is based on observation and reliable information; the deeper portion is hypothetical.

of faults in this central area as well as flexures or sudden changes of dip. Even where the beds are flat at the surface a drill hole may intersect inclined strata at a depth, showing that the flatness of the surface outcrops can not be relied upon as indicating the lack of disturbance in the beds beneath. The flexures with westward dips seen in the James River bluffs also make it probable that coal beds in that section will be found with occasional sudden downthrows along faults or flexures as the coal is followed toward the western margin, where the strata rise again toward the surface.

There are no well-marked horizons of peculiar rocks overlying the coal which will serve as a guide to the drillman in indicating how far he may be at any given time above the coal beds. Boring should be continued until coal or the light-colored granitic or gneissic basement is encountered. Care should be taken to avoid sinking a drill hole upon one of the numerous trap dikes which intersect the field. Preferably a drill hole should be sunk to the west of a known dike, fault, or flexure shown at the surface, for the reason that the dip of these



PLAN AND SECTIONS OF OLD WORKINGS ON EASTERN BORDER OF RICHMOND BASIN.

(After Clifford.)

secondary structures, so far as known in the central portion of the field, is steeply eastward. To drill near the eastern margin of these disturbances may be to encounter them lower down. The trap is normally a hard, dense, black crystalline rock, but where it is in contact with or has intersected a coal bed and converted the latter partly or wholly into natural coke, the trap is also altered into a soft white rock resembling clay. Intrusive sheets of this rock are to be expected in the coal measures in any part of the field.

THE COAL.

NUMBER, THICKNESS, AND EXTENT OF THE BEDS.

On the eastern margin of the main basin there are usually three workable beds. At Gayton, on the north side of the James, Coryell

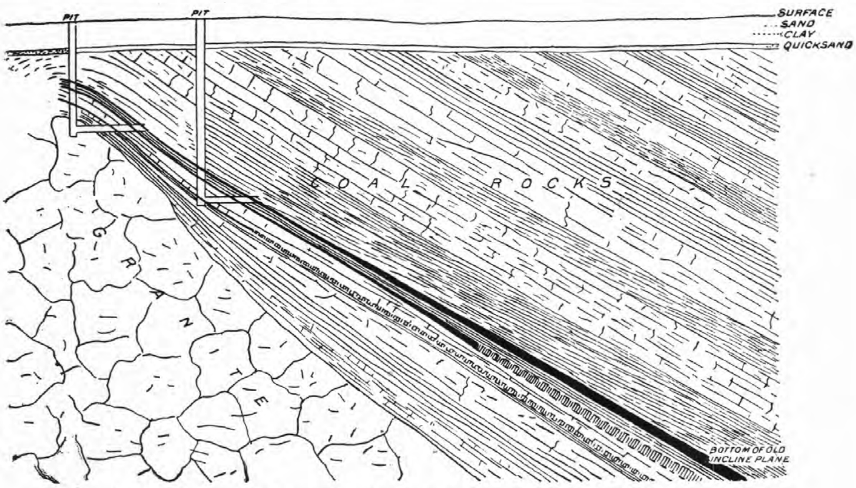


FIG. 2.—Section at the Powhatan Coal Company's colliery. (After Bladon.) Scale: 1 inch = 130 feet.

found four; the uppermost was unexplored, that next below was 6 feet in thickness, the next 5 feet, and the lowest, mainly natural coke, 6 feet. According to Daddow and Bannon, there is in this field, 50 feet above the granite, a bed of lean iron ore (15 to 20 per cent) 2 to 8 feet thick. Above this is a bituminous coal bed from 5 to 10 feet thick, but banded with slate; over this is a 4-foot bed, which is succeeded by a good workable coal from 5 to 7 feet thick. The upper or natural coke bed ranges from 5 to 6 feet.

In the abandoned Sallé and Burfoot tracts on the south bank of the James, near the site of Bellona arsenal, Lyell found the upper bed to be 30 feet, the middle 3 feet, and the lower 1 foot thick.

In the old workings at Midlothian one bed is described as having an average thickness of 20 feet, being 36 and as much as 50 feet thick in places. Heinrich reports three beds encountered in a boring near Grove shaft south of Midlothian of which the upper had a thickness of 14.5, the middle 12 feet, and the lower 3.5 to 4 feet. At Winterpock (Clover Hill), three beds were encountered, the middle one being the thickest. The developments have not been sufficiently extended to show as yet whether the beds are continuous from mine to mine along the eastern margin. It is the opinion of miners that they are not. But both the present and abandoned mines are reported to show a good breast of coal at the lower end of the slopes which have been driven down the dip.

On the western margin, at Manakin, three beds were encountered, the upper from 6 to 8 feet in thickness, the middle 12 feet, and the lower 3 to 4. In the Powhatan Coal Company's workings on the south side of the James there is an upper bed increasing from 2 feet near the surface to 10 feet at a depth of 400 feet, with two beds of less well-known thickness below. (See John Bladon's section, fig. 2, p. 35.)

The thickness of the coal beds and their known extent under the basin in the region bordering the James River furnish presumptive evidence that the beds are continuous beneath this portion of the area. Judging from structures observed at the surface, the coal beds probably occur at a somewhat less depth than in the southern parts of the basin.

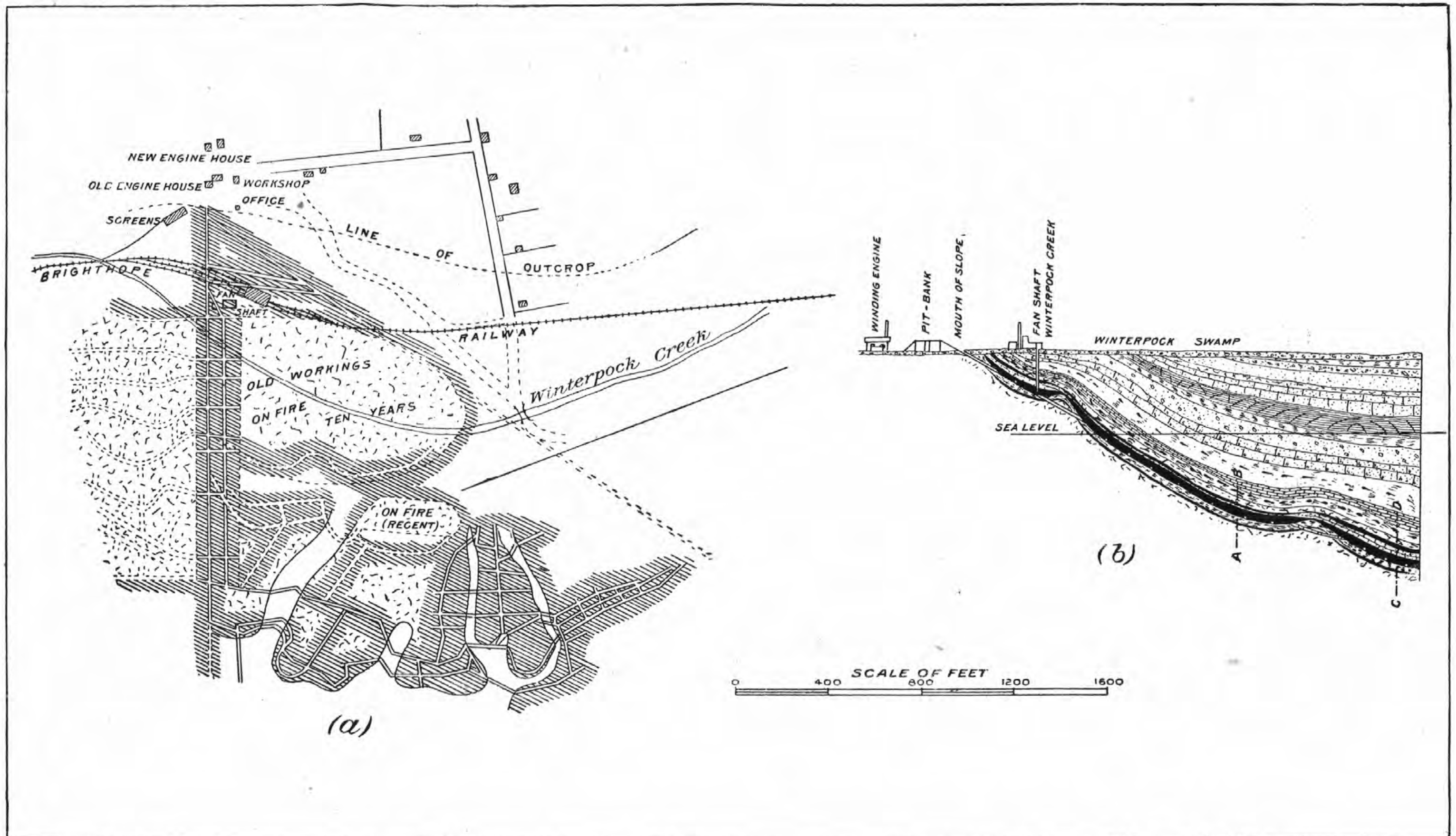
The accompanying figures (Pls. III and IV), reproduced from Clifford's report, show the available knowledge concerning the extent of the coal at Jewett's coke shaft (long abandoned), at Midlothian, in the Blackheath area (worked out), and at Winterpock.

CHARACTER OF THE COALS.

The coal of the Richmond Basin is normally bituminous and coking. Some years ago a few coke ovens were erected at Gayton and a limited amount of good coke was produced, which found a ready market in Richmond. In the portion of the basin northward from the vicinity of Midlothian at least one of the beds is usually converted, either wholly or partly, into natural coke or carbonite.

NATURAL COKE, OR CARBONITE.

The natural coke occurs associated with intrusions of diabase, either in the form of dikes which cut upward across the beds or as sills which follow the coal bed on the rise. These sills and certain of the dikes have been altered into soft gray rock, and in immediate contact with them the coke assumes a prismatic habit. This coke is cellular, burns slowly unless under a strong draft, snaps when burning, and is known as hard or "popping coke." The best variety, found more remote from the igneous rocks and known as soft or free-burning coke, occurs in rather dense blue-black masses suitable for household purposes.



PLAN AND SECTION OF RACCOON MINE, NEAR WINTERPOCK.

(After Clifford.)

The following analyses of natural coke from the Richmond Basin show its composition:

Analyses of coke from Richmond Basin.

Constituent.	I.[a]	II.[b]
Carbon	80.30	67.13
Volatile matter	9.98	18.35
Ash	9.72	12.86
Water	....	1.66
Sulphur	....	4.70

[a] Coke from a heavy bed on the eastern margin near the James River; W. B. Rogers, Geology of the Virginias, reprint, 1884, p. 535.

[b] Natural coke collected by I. C. Russell from Midlothian: Bull. U. S. Geol. Survey No. 42, 1887, p. 146. Analyst, R. B. Riggs.

At Gayton (Carbon Hill) the lower bed is coke. When examined by the writer in 1897, in the Saunders slope at a depth of 650 feet from the surface, the coke bed was about 9 feet thick, the lower 2 feet being relatively unaltered coal.

ANALYSES OF THE COALS.

W. R. Johnson presented in 1844 an exhaustive report on the steaming and other properties of the Richmond coals, for the numerous details of which his report should be consulted. The following data are taken from his work.

Synoptical view of the characters and composition of certain coals from the Richmond area, according to W. R. Johnson (1844).[a]

Designation of coal.	Density.				Composition in 100 parts.						Fuel ratio.
	Specific gravity.	Pounds per cubic foot, calculated from specific gravity.	Weight in pounds per cubic foot by experiment.	Cubic feet of space required to stow 1 ton.	Moisture, determined by steam drying.	Volatile matter, other than moisture.	Fixed carbon.	Sulphur.	Coke.	Earthy matter.	
Barr's Deep Run	1.382	86.410	53.174	42.126	1.785	19.782	67.958	....	78.433	10.475	3.43
Crouch and Snead's	1.451	90.710	53.593	41.797	1.785	23.959	59.976	0.427	74.256	14.280	2.50
Midlothian (900-foot shaft), average	1.437	87.497	50.518	44.340	1.172	27.278	61.083	....	71.550	10.467	2.62
Midlothian, average	1.294	80.895	54.044	41.450	2.455	29.796	53.012	0.058	67.749	14.737	2.20
Midlothian, screened	1.283	80.210	45,722	48.990	1.785	34.497	54.063	0.202	63.718	9.655	1.84
Clover Hill	1.285	80.355	45.485	49.250	1.339	31.698	56.831	0.514	66.963	10.132	2.11
Chesterfield Mining Co	1.289	80.565	45.549	49.180	1.896	30.676	58.794	1.957	67.428	8.634	2.20

[a] Report of experiments on the evaporative power and other properties of coals, made under authority of the Navy Department of the United States. 28th Cong., 1st sess., Senate No. 386, pp. 1-607; see pp. 308-451. 1844.

Analyses of coals given by Prof. W. B. Rogers, 1840.[a]

Designation of coals in 1840.	Fixed carbon.	Volatile matter.	Ash.	Color of ash.
FROM NORTH SIDE OF JAMES RIVER.				
Capt. Thomas M. Randolph's	66.15	30.50	3.35	Light red.
Coalbrookdale, second seam	66.48	29.00	4.52	Light gray.
Anderson's pits, first seam	66.78	28.30	4.92	Do.
Barr's pits:				
First seam	70.80	24.00	5.20	Faint red.
Second seam	54.97	22.83	22.20	Strong red.
Third seam	65.50	24.70	9.80	Light brown.
Fourth seam	56.07	21.33	22.60	Strong red.
Crouch's lower shaft, upper seam, 110 feet below surface.	64.60	30.00	5.40	
Scott's pits, formerly Woodward's	60.86	33.70	5.44	Light gray.
Waterloo shaft	55.20	26.80	18.00	
Deep Run pits	69.84	25.16	5.00	
FROM SOUTH SIDE OF JAMES RIVER.				
Stonehenge	58.70	36.50	4.80	Light reddish.
Engine shaft:				
Maidenhead	63.97	32.83	3.20	Strong red.
Heth, Potts & Co	62.35	37.65	2.80	Reddish yellow.
Mills and Reids Creek pit	57.80	38.60	3.60	Buff.
Will's pit	62.90	32.50	4.60	Light brown.
Greenhole shaft	67.83	30.17	2.00	Light red.
Colonel Heth's deep shaft (seam 30 to 40 feet thick):				
Bottom of seam	53.36	35.82	10.82	Light pinkish brown.
Middle of seam	66.50	28.40	5.10	Light brownish yellow.
Top of seam	61.68	28.80	9.52	Light pink to brown.
Powhatan pits, formerly worked by Captain Finney.	59.87	32.33	7.80	Pale buff.

DEVELOPMENT.

HISTORY.

The occurrence of coal in this area was known as early as 1700, and the coal was used as early as 1775. In 1789 shipments were made to Northern cities. A bed 24 feet thick was mentioned by Volney in 1803. According to Mease,[b] the general use of the coals in Richmond as early as 1807 was credited with lessening the febrile ailments of the inhabit-

[a] Geology of the Virginias, reprint, 1884, pp. 533–535.
[b] A Geological Account of the United States, by J. Mease, Philadelphia, 1807, p. 413.

ants. This medical opinion of the time is mentioned here as showing the general use of the coal at this period. The unusually thick beds of coal in the small detached basins on the eastern margin were early and quickly won, and during the thirties and forties the mining operations here were the most extensive in the United States. English capital later became interested in the Midlothian field, and a durable pumping shaft house and other structures were erected, only to be abandoned because the coal bed appeared to be local and worked out.

Three fields on the eastern outcrop of the main basin have been long worked in a small and intermittent way north of the James at Gayton (or Carbon Hill), the vicinity of Midlothian, and at Winterpock (Clover Hill of the old reports). A small amount of coal is still being mined at Gayton and Winterpock. The Midlothian field was abandoned a few years ago because of the burning of the surface equipment, but not, it is stated, for lack of coal in sight in the workings. On the western margin the Norwood, Old Dominion, and Scott's pits, on the south side of the James, and the Manakin mine, on the north bank of the river, were worked to a small extent, but have for many years been abandoned.

An attempt to reach the coals near Midlothian was made in 1874 by the "sinking shaft," which was abandoned before the horizon at which the coal occurs was reached. At present the deeper lying coals are reached at Gayton and Winterpock by slopes driven down from the eastern outcrop or driven from the foot of shafts sunk near that outcrop.

METHODS OF MINING.

The larger mines in the best days of this field were worked on the English plan by means of shafts and slopes. An inspection of Clifford's plans of the Raccoon coal mine near Winterpock (Pl. IV), of Jewett's coke shaft, and the old Black Heath workings (Pl. III), will give an idea of the method of entering the ground. Water has been raised largely by means of buckets, and in many ways the methods employed have been rather those of the early part of the century than those now most approved. The shafts are sunk to depths determined by the distance from the outcrop. North of the James there were at one time as many as twelve of these shafts within a mile. Graham's or Anderson's shaft was 450 feet deep. On the south side of the James the shafts were from 400 to 500 feet deep. The Midlothian Company's shaft reached the coal at a depth of 722.5 feet and went through 36 feet of coal, with a sump 16.5 feet deep. The Gowrie shaft was 460 feet deep.

The gaseous nature of the coals has led to a few serious explosions, fires, and much loss of life. The first explosion took place in 1817. In 1839 an explosion took place in one of Heath's pits by which 53 out of 56 persons in the mine were lost. Other explosions had previously occurred in the Maidenhead pits. Explosions took place in 1841 in Will's pits, in 1844 in the Blackheath basin, and in 1854 19 men were killed in the Chesterfield coal pits, then over 600 feet deep. In 1854 or 1855 an explosion took place in the Midlothian Coal Company's shaft by which 55 men were killed In 1835 the Blackheath mines were on fire, and the Bell workings had been on fire for twenty-five years. The history of these accidents shows the need of the most improved means of ventilation in this field.

LABOR EMPLOYED.

In the earlier days colored labor was largely employed under the supervision of English and Welsh miners. At present Hungarian and colored labor, under the direction of local and Pennsylvania mining engineers, is employed. No accurate statistics exist as to the number of men or the wages paid.

STATISTICS OF MINES AND PRODUCTION.

Accurate statistics of the mines and of the production of this field, particularly in its former best days, are wanting. R. C. Taylor estimated the production for twenty years as follows:

Estimated coal production of Richmond Basin from 1822 to 1842.

	Tons.		Tons.
1822	48, 214	1836	110, 714
1824	59, 857	1838	96, 428
1826	79, 214	1839	85, 714
1828	89, 357	1840	78, 571
1830	91, 786	1841	71, 071
1832	117, 857	1842	65, 750
1834	110, 714		

According to the census of 1870, 61,803 tons were mined in the State of Virginia, most of which probably came from this field. According to the Tenth Census report, 40,520 tons were mined in the Richmond area in 1880. The following statistics have since appeared; those from 1895 to 1900 are from transportation companies:

Statistics of coal production in Richmond Basin from 1885 to 1892 and 1895 to 1899.

	Tons.		Tons.
1885	50, 000	1896 [a]	1
1886	28, 000	1897 [a]	130
1887	50, 000	1898 [a]	53
1892	33, 600	1899 [a]	21
1895 [a]	1, 076		

The mines in this field have frequently changed hands. The references cited by Russell give a clue to the names of many firms engaged in this field in the past.

[a] From Midlothian only. Since 1896, largely shipments by individual miners from old workings.

According to the Mining Directory of the Tenth Census[a] the following mines were working in Chesterfield County, Va., in 1880:

1. Bright Hope, at Clover Hill, operated by Bright Hope Railroad Company; top, middle, and bottom seams, 27 to 30 feet thick; product in tons of 2,000 pounds, 19,040. Markets, Richmond, Petersburg, Norfolk, Va., and tide-water cities on Atlantic coast.

2. Cunliff mine, at Coalfield, operated by George H. and John Jewett; product, 6,720 tons; thickness of seams, 25 feet. Market, Richmond, Va.

3. Union mine, at Midlothian. Operator, Jacob Baach; product, 1,638 tons; thickness of coal, 8 feet. Market, Richmond, Va.

5. Midlothian mine, at Midlothian. Operator, R. S. Burrows; product, 13,122 tons; thickness of coal, 4⅔ feet. Market, Richmond and Manchester, Va.

At present there are but two companies operating in the field—the Virginia Coke and Coal Company at Winterpock (Clover Hill) and a company at Gayton on the north side of the James. The latter company also controls the Grove shaft, which has not been reopened since the burning of the surface works a few years ago.

PROSPECTIVE DEVELOPMENT.

The present operators hold to the policy of reaching the central portion of the basin by means of existing slopes and shafts sunk on the eastern outcrop, and are thus following the coal without testing the ground in advance of their workings by means of the drill. While this policy obviates the expense of drilling and the initial cost of deep shafts in the middle of the basin, its continuance must leave for several years the actual occurrence of workable beds of coal in the central portion of the basin a matter of inference, with the prospect that the lengthening of existing slopes must ever increase the cost of bringing the output to the surface. None of the borings so far made at a distance from the margin have penetrated to the crystalline basement so as to reveal the number, thickness, or extent of the coal beds which may underlie the area.

DISTRIBUTION.

LOCATION OF MARKETS.

In the past a market has been found for the Richmond coals in Richmond and in the seaports along the North Atlantic coast. Prior to the introduction of the western coals a relatively large amount was used for gas making in Philadelphia, and within recent years the natural coke has sold in the Boston market at $3.50 a ton.

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[a] Tenth Census U. S., Vol. XV, p. 927.

PRESENT ROUTES TO POINTS OF CONSUMPTION.

The coals from Gayton are moved by a private railroad to Lorraine, where connection is made with the James River division of the Chesapeake and Ohio, connecting with Richmond and West Point. The Grove shaft, near Midlothian, has a connection with the Southern Railway at Midlothian, allowing transportation to Richmond. The Farmville and Powhatan narrow-gage road crosses the southern part of the field, carrying the Winterpock coals to Chester, a connection on the Seaboard Air Line, from which distribution can be made to cities and towns along the edge of the Coastal Plain.

FARMVILLE AREA.

LOCATION AND BOUNDARIES.

This area lies in Buckingham, Cumberland, and Prince Edward counties, Virginia, about midway between the eastern and western Triassic belts. Farmville is a station on the Norfolk and Western Railroad and the terminus of the Farmville and Powhatan narrow-gage railroad. The area has a northeast-southwest extension of 20 miles and a maximum width of about 5 miles, with a surface of 60 square miles. The southern part of the area forms a small detached basin 6 miles south of Farmville, being separated from the main basin by nearly 2 miles of mica-slate, gneiss, granite, etc., exposed in the vicinity of King's tavern. The entire area is surrounded by the rocks of the Piedmont district. Granite occurs on the eastern border.

GEOLOGIC RELATIONS.

AGE OF THE STRATA.

The rocks are of Triassic age, and in general show a close correspondence with the section in the Richmond area on the east.

STRATIGRAPHY.

The details of the stratigraphic succession have not been definitely determined. W. B. Rogers gave the following list of strata crossed north of the Appomattox River going from Raine's tavern toward Kurdsville:

Strata crossed north of Appomattox River going from Raine's tavern toward Kurdsville.

1. Near the tavern the margin of the area appears, with soft gray sandstones, with vegetable impressions, and a thin seam of carbonaceous matter exposed on the farm of William S. Walton (1839).
2. Red and green shales and sandstones, hard and soft, for nearly 2 miles.

3. Yellowish and brown soft sandstones, and near Cook's mill a ledge of bluish slaty sandstone, containing a spiral univalve shell and rhombic fish scales.
4. Yellowish and reddish shales and sandstones.
5. On the western margin, an extremely coarse conglomerate, composed of fragments of the rocks of the Piedmont region.

STRUCTURE.

Our knowledge of the structure of the area is mainly due to a reconnaissance made by I. C. Russell in 1885.[a] According to this geologist, the strata are much disturbed, sometimes dipping to the west and sometimes to the east. At least four north-south faults affect the central portions of the area. On the eastern border, about 2 miles north of Farmville, a heavy marginal fault has been shown in mines. Here the coal-bearing beds abut against granite. In the small area on the south the prevailing dip is 20° W. No faults have here been detected and no folds are known.

THE COAL.

A number of thin seams of coal have been found. W. B. Rogers reported the existence of a seam of bituminous coal nearly 2 feet thick in the southern end of the southern basin. Several very thin seams of coal were also encountered in dark shales and brown sandstones in borings at Morton's mills and on the Bizarre estate (1839). Professor Rogers stated that the material of these seams is usually a friable mixture of carbonaceous and earthy matter, in some places assuming the appearance of a hard bluish-black mass of rather porous texture, resembling coke. Dikes occur in the area. In his official report, Rogers discouraged attempts at mining coal in this field. No important discoveries of coal have been reported since his time.[b]

DEVELOPMENT.

The field is practically undeveloped, and beyond the thin seams of unsatisfactory coal found about the margin nothing is known of the basin at a depth.

The field is crossed by the Norfolk and Western Railway, connecting on the west with Lynchburg and on the east with Petersburg, City Point, and Norfolk.

DEEP RIVER AREA.

There are two coal-bearing Triassic areas in North Carolina shown on the map (Pl. V). These are the eastern or Deep River area, including the Wadesboro detached area, and the western or Dan River

[a] Bull. U. S. Geol. Survey No. 86, 1887, pp. 88-89.
[b] Reprint of Annual Reports and other papers on the Geology of the Virginias, New York, 1884, pp. 327-328.

area. The principal productive coal beds are found in the Deep River district, in Chatham and Moore counties. The Dan River region is regarded as of little promise. The relations of the two fields are shown in the diagram (fig. 3).

LOCATION AND EXTENT.

The Deep River area forms a northeast-southwest belt in the central portion of the State, extending northward nearly to the Virginia line and southward into South Carolina. The productive area, about 30 miles long, lies wholly within North Carolina.

The rocks of the area appear on the north about 6 miles southeast of Oxford, in Granville County, whence they extend southwestward to the Cape Fear River. South of this stream they continue as a somewhat tortuous belt in the Deep River region to within about 10 miles of the Yadkin River. On the Yadkin, and a few miles west of the southern end of the Deep River area proper, the Wadesboro area begins and extends in the same general direction 6 or

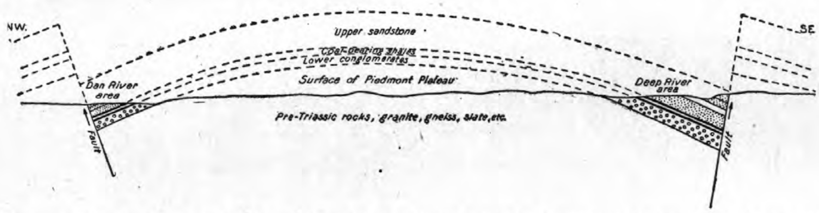


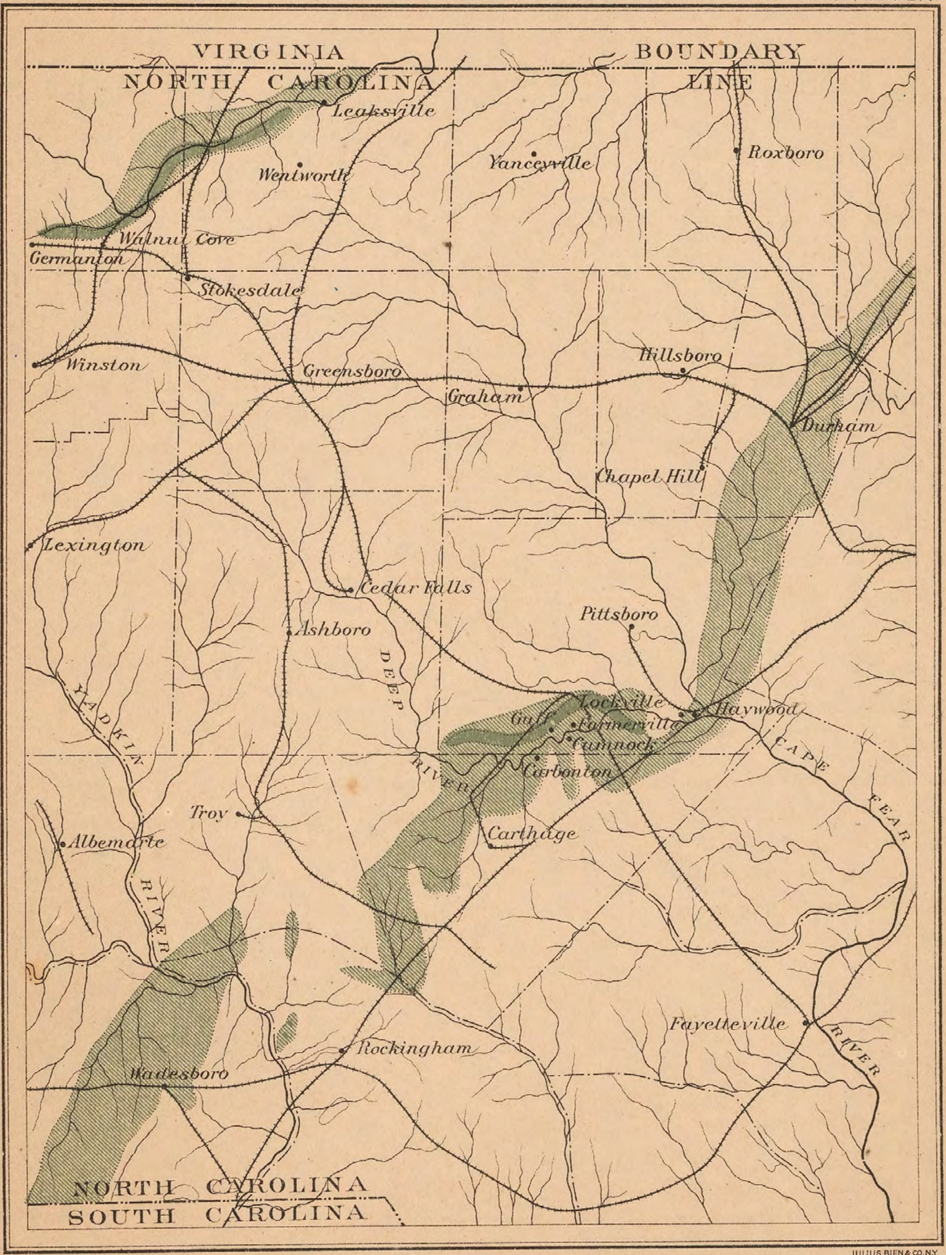
FIG. 3.—Section showing probable relation of Dan River and Deep River Triassic areas. The eastward dip of the beds in the Deep River area is generalized; westward dips also occur.

7 miles into South Carolina, in the vicinity of Carew. The total length of the whole belt is over 60 miles. Its average width is about 12 miles, its greatest width being as much as 18 miles. The total area has been estimated at between 250 and 300 square miles. Between the larger northern and southern areas are small detached basins of Triassic rocks not known to be coal bearing.

GEOLOGIC RELATIONS.

STRUCTURE.

The area displays the prevailing structure of the Triassic belts along the Atlantic coast, the basal strata of one side of the belt reposing on the ancient crystalline rocks of the Piedmont district, the opposite margin bearing evidence of being thrown down by faults. The usual dip of the strata in this area is southeast, the angle being about 15°. According to Russell, the notches in the boundaries probably indicate faults, several of which are exposed in railroad cuts within the area. Evidence of faulting is also seen in the narrow strip of Triassic strata near the western border, in the vicinity of Lockville.



DEEP AND DAN RIVER COAL BASINS

NORTH CAROLINA

After Kerr

Scale

0 5 10 20 30 40 MILES

LEGEND

Triassic areas

Productive areas

The coal-bearing beds show a distinct curvature where crossed by the Deep River northeast of Cumnocks. In other respects the structure, as revealed in workings, appears to be more regular than that of the Richmond area in Virginia.

STRATIGRAPHY.

The strata, numbered from the bottom upward, are given as follows in the State reports:

Strata in Deep River area, North Carolina.

	Feet.
3. Sandstones, grits, and upper conglomerates	3,000
2. Black shales, with coal beds	500 to 600
1. Conglomerates and sandstones	1,500

THE COAL.

NUMBER, THICKNESS, AND EXTENT OF THE BEDS.

As in the Richmond and other Triassic areas, the coal beds are near the base of the Newark formation. The coal-bearing strata have been well exposed in the old shaft at Egypt, now Cumnocks. Fig. 4 is reproduced from the report on this mine made by Captain Wilkes in 1858.

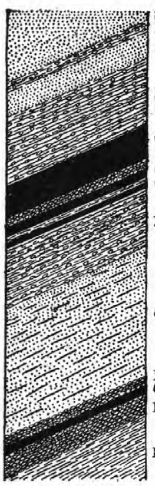


FIG. 4.—Section of strata exposed in the old Egypt shaft. (After Wilkes, 1858.)

Five coal seams have been proved at the Farmville and Hornesville mines. Their thicknesses, beginning with the highest, are given as 3, 1, 3, 2, and 4 feet. At the Cumnock mine there are two beds, one 4 and the other 2 feet in thickness, separated by 2 feet of blackband iron ore. At Taylor's mines three seams were reported, with a thickness of from 18 to 30 inches, 2.5 to 3 feet, and 4 feet, respectively. At Wilcox's the Murchison seam is described as being 8 or 9 feet thick, but containing shale. The coal outcrop has been traced for 30 or 40 miles in the central part of the State southwestward from the vicinity of the Cape Fear River.

The accompanying sketch map and section (figs. 5 and 6), by Kerr, show the position of the outcrop and details of the coal section near Gulf.

Chance[a] found at Farmville, N. C., five beds of coal in the following section, which measured 40 to 50 feet from the roof of the uppermost coal bed to the floor of the lowest.

[a] Trans. Am. Inst. Min. Eng., Vol. XIII, pp. 517-520.

Section of coal beds at Farmville, N. C.

Slate roof.
Coal, good .... 3 feet to 3 feet 2 inches.
Blackband and slate .... 1 foot 8 inches to 3 feet.
Coal, poor, shaly .... 1 foot to 2 feet.
Pure clay floor.

CHARACTER AND CHEMICAL COMPOSITION OF THE COAL.

The coal is normally bituminous, but owing to the coking action of intrusive rocks passes locally into anthracite and even a graphitic vari-

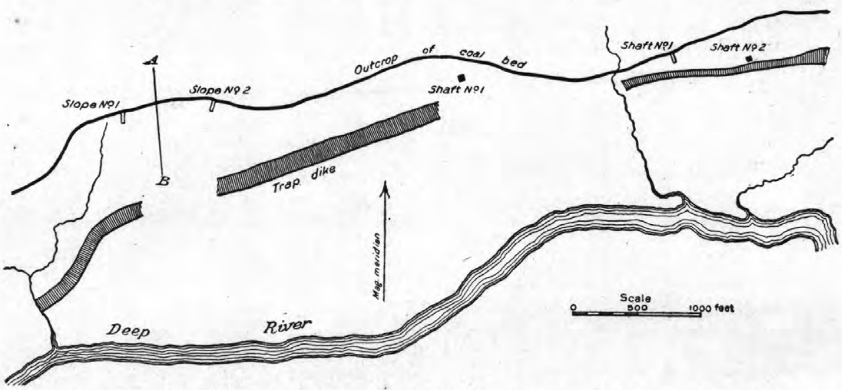


FIG. 5.—Sketch map showing outcrop of coal at Gulf, Chatham County, N. C. (From W. C. Kerr Report on the Geological Survey of North Carolina, Vol. I, 1875, p. 144.)

ety. On the other hand, semibituminous varieties have been encountered. The bituminous coal is rated as excellent. It burns freely, cakes, or partly fuses and agglutinates, forming a partly impervious hollow cake in which combustion goes on for a long time. It may be ignited in the blaze of a candle, and burns with a bright flame. It makes excellent coke and illuminating gas, and is free from sulphur (MacFarland). The coal leaves very little purplish-gray ash.

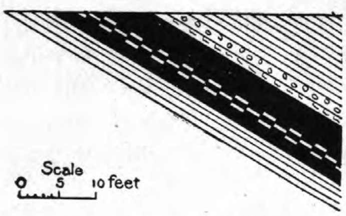


FIG. 6.—Section of coal at Gulf, Chatham County, N. C. (After Kerr.)

Natural coke or carbonite is reported as occurring in the old Wilcox mine, where it was known as "dry coal." Its outcrop corresponds in thickness with the upper seam, which farther north is unaltered.[a]

Above the coal Wilkes describes the shales as very inflammable and burning with a white flame. An analysis showed 20 per cent of fixed carbon and 30 per cent of volatile matter.[b]

[a] C. Wilkes, Report, p. 9. [b] Wilkes, loc. cit.

Analyses of coals from Deep River area, North Carolina.

Location.	Analyst.	Fixed carbon.	Volatile matter.	Ash.	Sulphur.	Water.	Fuel ratio.
Farmville:							
Lower seam—							
Sample I	Emmons[a]	50.70	30.91	18.32	....	....	1.64
Sample II	do	64.70	28.47	6.83	....	....	2.23
Sample III	do	63.90	30.85	5.25	....	....	2.06
Sample IV	do	64.40	31.30	4.30	....	....	2.06
Upper bed—							
Sample I	Battle[b]	58.30	29.56	7.46	2.89	....	1.97
Sample II	do	58.47	30.54	6.85	2.19	....	1.91
Lower seam—							
Sample III	do	60.59	28.66	5.35	3.69	1.71	2.11
Sample IV	do	51.24	28.71	14.51	4.18	1.36	1.79
Sample V	do	52.56	28.88	12.69	3.72	2.15	1.81
Sample VI	do	50.04	26.87	14.69	7.08	1.32	1.86
Egypt:							
Deep pit	Dr. Jackson[c]	63.60	34.80	1.60	....	....	1.82
Do	G. C. Shaefer[c]	60.70	32.70	5.30	1.30	....	1.82
Do	J. H. Cremer[c]	64.19	27.85	4.24	1.77	1.95	2.35
Do	Endeman[c]	63.32	31.42	4.12	1.99	1.14	2.01
Gulf, North Carolina:							
Upper bed, specific gravity 1.295.	F. W. Clarke[d]	72.44	24.48	3.08	.99	....	2.96
Middle bed, specific gravity 1.339.	do	67.86	24.22	7.92	1.42	....	2.80
Lower bed, specific gravity 1.359.	do	66.37	23.94	9.69	3.33	....	2.77

[a] Geological Report, Midland counties of North Carolina, 1856, pp. 247, 248.
[b] Chance, Trans. Am. Inst. Min. Eng., Vol. XIII, pp. 517–520.
[c] Collected by Russell; Bull. U. S. Geol. Survey No. 42, 1887, p. 146.
[d] State Board of Agriculture, North Carolina and its Resources, 1896, p. 104.

In Specimens I and II of Dr. Battle's analyses Chance describes the coal as friable, breaking down readily into a fine slack, and as coking quickly and thoroughly. Specimens III, IV, and V pertain to a coal which is hard, having a columnar structure and bright fracture, with very little pyrites; burning with a strong flame and coking slowly, not commencing to coke until highly heated.

In the analyses by Dr. Clarke the coke is described as good, the ash gray. The coals gained weight on drying at 115°.

DEVELOPMENT.

HISTORY.

Coal was discovered in this area in the latter part of the eighteenth century. The present productive field was exploited by shafts in the middle of the nineteenth century, but systematic mining may be said only to have begun with the reopening of the Egypt shaft at Cumnocks in 1889.

In the Mining Directory of the Tenth Census,[a] for 1880, the following mines were named in the Deep River area:

1. Gulf mine; operator, E. L. Houghton; product, 200 tons. Thickness of coal, 6½ feet. Market, Raleigh, Charlotte, Fayetteville, and Lawrenceburg.

2. Egypt mine. Not operated. Thickness of coal, 4½ feet. Market, Raleigh, Fayetteville, Portsmouth, and Wilmington.

According to the report of the State board of agriculture, the Cumnock mines (the old Egypt coal mine) were the only operating collieries in North Carolina in 1896. Operated in a desultory and primitive way before 1888, they were then enlarged and refitted under a new management. The colliery is operated by two perpendicular shafts; one, for ventilation only, measuring 8 by 10 feet, taps the vein in the rise workings at a depth of 220 feet; and the main working shaft is 8 by 12 feet and 464 feet deep. The plant in 1898 had a capacity of 1,000 tons per day.

The Cumnock Company owns 4,300 acres. The workable veins aggregate 6 feet in thickness, lying in two benches of 4 and 2 feet, separated by 2 feet of blackband iron ore. With a specific gravity of 1.31 for the upper seam and 1.43 for the lower, it is estimated that 11,000 tons to the acre, or 47,300,000 tons, exist within the holding of this company alone.

The Greensboro Gas Company reports that a quantity of this coal made 9,700 cubic feet of gas, 18.5 candlepower, and 49 bushels of good, clean, hard coke. It has proved successful as a locomotive coal. It was shipped as a blacksmith coal to local points on the Norfolk and Western Railroad. It is an excellent grate coal.[b]

At present the Chatham Coal and Iron Company, C. F. Pendleton, superintendent, is operating collieries at Cumnock, and the North Carolina Coal and Coke Company, George F. Cant, superintendent, is engaged in mining at Gulf.[c]

STATISTICS OF MINES AND PRODUCTION.

The use of coal from this field began in an irregular way early in the last century. Between 1860 and 1865 it is estimated that about 60,000 tons were taken out of the mines then in existence, and about 350 tons were mined in 1880. The systematic development of the old Egypt shaft, now the Cumnock property, began in 1889, and the following statistics, published in Mr. E. W. Parker's report for 1899, give the production to the close of that year. A fire in the mine curtailed the output in 1898.

[a] Tenth Census United States, Vol. XV, p. 899.

[b] State Board of Agriculture, North Carolina and its Resources, Winston, 1896, pp. 104-105.

[c] Letter of Prof. Collier Cobb, February 28, 1901.

Coal product of North Carolina since 1889. [a]

Year.	Short tons.				Total value.	Average price per ton.	Average number of days active.	Average number of employees.
	Loaded at mines for shipment.	Sold to local trade and used by employees.	Used at mines for steam and heat.	Total product.				
1889				192	$451			
1890				10,262	17,864			
1891	18,780	600	975	20,335	39,635	$1.93	254	80
1892	6,679			6,679	9,599	1.44	160	90
1893	15,000		2,000	17,000	25,500	1.50	80	70
1894	13,500	1,000	2,400	16,900	29,675	1.76	145	95
1895	23,400	600	900	24,900	41,350	1.66	226	61
1896	5,356	295	2,162	7,813	11,720	1.50	220	18
1897	21,280			21,280	27,000	1.34	215	51
1898	9,852	304	1,339	11,495	14,368	1.25		
1899	24,126	486	2,284	26,896	34,965	1.30	210	70

DISTRIBUTION.

The coal at Cumnocks is shipped directly by the Cape Fear and Yadkin Valley Railroad, connecting with the Seaboard Air Line at Colon by means of the Raleigh and Western Railroad, which in turn offers a connection with the Southern Railway in Randolph County.

It has found a good market along the Norfolk and Western Railroad as a blacksmith coal.

DAN RIVER AREA.

LOCATION AND EXTENT.

This area is the southern part of a belt which begins about 10 miles north of the Virginia line and extends southwestward into North Carolina through Rockingham and Stokes counties as far as Germantown, a distance of about 30 miles. It is separated by a few miles of Piedmont rocks from a nonproductive northern area which extends as far north as Appomattox County in Virginia. The breadth of the Dan River area is said to be not less than 4 and not more than 7 miles. It is surrounded by gneisses believed to be of Archean age.

[a] E. W. Parker, The production of coal in 1899: Twenty-first Ann. Rept. U. S. Geol. Survey, Pt. VI, p. 158.

GEOLOGIC RELATIONS.

The age of the beds is the same as that of the previously described areas, Upper Triassic.

STRATIGRAPHY.

The stratigraphy of the area is similar to that of the Deep River area, conglomerates at the base being overlain by the coal-bearing shales, which are succeeded by a thick sandstone series and fine conglomerate toward the top. Little available knowledge exists concerning the details of the bedding.

STRUCTURE.

The structure of the area is apparently that of a westward-dipping fault basin, with the downthrow and a fault or faults on the western margin. The rocks dip northwest. The angle of dip varies from 15° to 40°, and is usually greater than 20°.[a]

The strata are known to be intersected by a few trap dikes, which acted as coke makers where they cut the coal.

THE COAL.

The coal lies near the base between beds of shale. The outcrop of the coal-bearing series is mapped by Kerr from Germantown to near Leaksville. The main coal seam is said to be about 3 feet thick, varying from 2 to 7 feet. At Stokesburg there are three seams, the uppermost about 3 feet thick. One of the lower seams is reported to be much thicker. Near Leaksville, a slope was driven about 60 feet on the coal seam, which there is about 3 feet thick, and has a dip of 34°. Coal was mined here during the civil war. At Germantown, two beds of coal are reported, each 18 inches thick, separated by 1 foot of "slate."

Professor Holmes,[b] of the North Carolina geological survey, in 1891 drilled two holes near Walnut Cove, Stokes County, one going down 1,112 feet without encountering valuable beds of coal, thus preventing, it is claimed, many profitless mining operations. This geologist is of the opinion that the indications are more favorable near the southwest end of the basin, between Walnut Cove and Germantown.

The coal at Leaksville is classed as semibituminous or dry coal. It is brittle and crumbles readily in the air, but cokes easily, and is claimed to be a good gas coal.[c]

[a] The Coal Regions of America, by James MacFarland, 1873, p. 527, citing E. Emmons, Report, 1856, p. 255.

[b] First Biennial Report N. C. Geol. Survey, Raleigh, 1893, pp. 16–17.

[c] North Carolina and its Resources, 1896, p. 103.

ANALYSES.

The following analyses have been made of coals from this field:

Analyses of coal from Dan River area.

	I.[a]	II.[a]	III.[b]
Fixed carbon	75.96	76.56	55.47
Volatile matter	11.44	13.56	17.99
Ash	12.00	12.00	26.16
Sulphur	....	....	5.56
Water	....	....	.38

[a] Analyses by Dr. Genth, about 1871, from coal near Stokesburg.
[b] Coal from Walnut Cove, Stokes County; analysis by J. E. Whitfield, in Bull. U. S. Geol. Survey No. 42, 1887, p. 146.

DEVELOPMENT.

No coal has been shipped from this area in many years, and the probabilities are that the seams of merchantable coal are too thin to repay working under the existing conditions of mining coal in other fields.

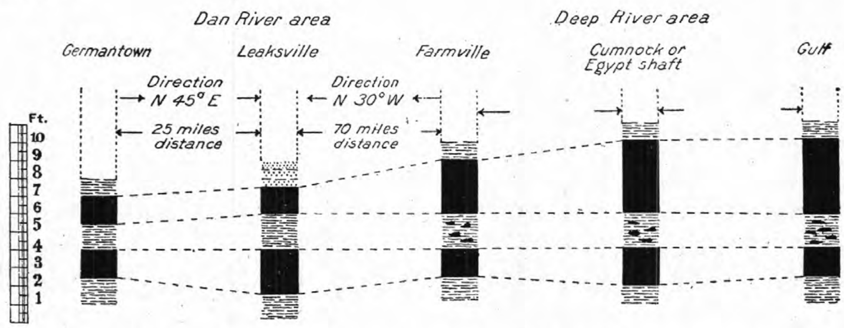


FIG. 7.—Columnar sections of coal beds in the Dan River and Deep River areas. Dotted lines indicate supposed original continuity of strata. Dip corrected.

The explorations carried on by the State board of agriculture adjacent to the Dan River are described in Mineral Resources of the United States for 1887, pp. 280–281. It should be noted that the promising conditions there cited from the report of the State engineer were later regarded as fallacious by the State geologist, and the area is now held to be practically worthless.

The accompanying figure (fig. 7) of the coal beds in North Carolina is intended merely to show the supposed correlation of the strata in the Deep River and Dan River areas. The dotted lines indicate supposed continuity of original bedding. The dip of the strata has been corrected for the purpose of comparison

POSSIBLE EXISTENCE OF TRIASSIC COAL BASINS BENEATH THE COASTAL PLAIN.

The fact that a boring through the Coastal Plain near Florence, S. C.,[a] penetrated a patch of the Triassic in that region makes it reasonable to expect that other Triassic areas lie east of the Richmond and Deep River areas outside of the fall line and under a thick cover of newer Mesozoic sands and clays. Even if such areas proved to be coal bearing it is hardly possible that this source of supply will be exploited until the existing fields having a surface exposure have been exhausted.

SUMMARY OF PRODUCTION.

The following table shows the production of the Atlantic coast Triassic coal fields for the twenty years from 1880 to 1900:

Development of the Atlantic coast Triassic coal field by decennial periods.

Locality.	1880.			1890.		
	Production.	Value.	Average price per ton.	Production.	Value.	Average price per ton.
Chesterfield and Henrico counties of Virginia, and North Carolina	*Tons.* 43, 429	$100, 202	$2. 30	*Tons.* 45, 262	$77, 864	$1. 72

Locality.	Increase of 1890 over 1880.				1900.		
	Production.	Per cent.	Value.	Per cent.	Production.	Value.	Average price per ton.
Chesterfield and Henrico counties of Virginia, and North Carolina	*Tons.* 1, 833	4	[b]$22,338	22	*Tons.* 57, 912	$103, 777	$1. 79

Locality.	Increase of 1900 over 1890.			
	Production.	Per cent.	Value.	Per cent.
Chesterfield and Henrico counties of Virginia, and North Carolina	*Tons.* 12, 650	27	$25, 913	33

[a] N. H. Darton, Bull. U. S. Geol. Survey No. 138, p. 218.

[b] Decrease.

LITERATURE.

Russell, I. C. Correlation papers—The Newark system: Bull. U. S. Geol. Survey No. 85, Washington, 1892.

This work contains an analytic list of all books and papers published in relation to the Newark areas up to the date of issue. The following papers relate to the coal-bearing areas.

Rogers, W. B. Reprint of annual reports and other papers on the geology of the Virginias, New York, D. Appleton & Co., 1884.

Shaler, N. S., and Woodworth, J. B. Geology of the Richmond Basin, Virginia: Nineteenth Ann. Rept. U. S. Geol. Survey, Pt. II, 1899, pp. 385–519.

Emmons, Ebenezer. Report of Professor Emmons on his geological survey of North Carolina, Raleigh, 1852, pp. 113–159.

Wilkes, C. Report on examination of Deep River coal field: Thirty-fifth Congress, second session, Doc. 26, vol. 7, 1858–59, pp. 1–29, pls. 1, 2, maps.

Kerr, W. C. Report of the geological survey of North Carolina, Vol. 1, Raleigh, 1875, pp. 141–147, 293–295.

THE PENNSYLVANIA ANTHRACITE COAL FIELD

BY

H. H. STOEK

CONTENTS.

ILLUSTRATIONS.

THE PENNSYLVANIA ANTHRACITE COAL FIELD.

By H. H. Stoek.

GEOGRAPHIC RELATIONS.

LOCATION AND BOUNDARIES.

The anthracite coal field of Pennsylvania is located in the east-central part of the State, mainly within Lackawanna, Luzerne, Carbon, Schuylkill, and Northumberland counties. In these five counties anthracite mining is the dominant and characteristic industry. The anthracite measures, however, overlap into Wayne, Susquehanna, Wyoming, Sullivan, Columbia, Dauphin, and Lebanon counties.

Speaking broadly, the anthracite field may be said to be bounded on the west by the Susquehanna River, on the north by the North Branch of the Susquehanna, and on the east by the Delaware and Lehigh rivers. These three rivers, together with the Schuylkill, form the drainage outlets for the region.

The anthracite region embraces a territory of about 3,300 square miles, but less than one-fifth of this total area, or about 484 square miles, is underlain by workable coal measures. This productive portion is, moreover, not a continuous area, but consists of a number of detached valleys, or basins, as is shown in Pl. VI. The general trend of these valleys is N. 60° to 70° E. They are arranged en echelon from northeast to southwest, making the greatest length about 120 miles along a line extending from Forest City to Dauphin. The greatest width is 30 miles, between Mauch Chunk and Shickshinny, or 50 miles if the northern limit be extended to the outlying Bernice basin.

SUBDIVISIONS OF THE FIELD.

The region is subdivided from several different standpoints: (1) Geologically and geographically into 4 primary and 29 secondary divisions; (2) for mine inspection purposes, into 8 districts; (3) for trade reasons, into 3 main regions and 18 minor regions; (4) from the labor standpoint, into 3 districts.

Subdivisions of Pennsylvania anthracite coal field.

Geographic subdivisions of second geological survey of Pennsylvania.	Geologic field or basin.	Mine inspector's district.	Trade district.	Labor district.
1. Forest City-Carbondale division	Northern:			
2. Jermyn-Priceville division	Carbondale	First		
3. Scranton division	Scranton	Second		
4. Pittston division	Pittston	Third	Wyoming	District No. 1 (anthracite).
5. Wilkesbarre division	Wilkesbarre			
6. Nanticoke-Mocanaqua division	Plymouth	Fourth		
	Kingston			
7. Loyalsock-Mehoopany division	Western-northern			
8. Upper Lehigh-Pond Creek basin				
9. Woodside and Cross Creek basin				
10. Little Black Creek basin	Eastern-middle:			
11. Big Black Creek basin	Green Mountain			
12. Black Creek, Roberts Run, and McCauley basins	Black Creek			
13. Hazleton basin	Hazleton			
14. Dreck Creek and Beaver Meadow basin	Beaver Meadow			
15. Green Mountain basins Nos. 1–5		Fifth	Lehigh	District No. 7 (anthracite).
16. Spring Mountain basin and Silver Brook basin				
23. Panther Creek				
21. Broad Mountain				
22. Heckscherville Valley	Southern:			
24. Tamaqua-Middleport	Panther Creek			
25. Pottsville	East Schuylkill			
26. Llewellyn-Tremont	West Schuylkill	Eighth		
27. East Franklin-Brookside	Lorberry			
28. Williamstown-Lykens	Lykens Valley			
29. Schuylkill-Dauphin			Schuylkill	District No. 9 (anthracite).
17. Mahanoy Basin, Delano Shenandoah division	Western-middle:	Seventh		
18. Lost Creek-Locust Gap division	Shamokin			
19. Centralia-Mount Carmel division	West Mahanoy			
20. Shamokin-Trevorton division	East Mahanoy	Sixth		

GEOGRAPHIC AND GEOLOGIC DIVISIONS.

There are four of these divisions, the northern, containing 176 square miles; the eastern-middle, containing 133 square miles; the southern, containing 181 square miles; and the western-middle, containing 94 square miles.

NORTHERN BASIN.

The northern, or Wyoming-Lackawanna, basin extends from Forest City to Shickshinny, a distance of 55 miles, and includes the Wyoming and Lackawanna valleys. The maximum width is 6 miles, and the map (Pl. VI) shows the field to be crescent shaped, with the upper or northeastern extremity bending sharply toward the north. The Lackawanna River drains the upper, or Lackawanna Valley, and empties near Pittston into the Susquehanna, which breaks through the hills from the north just above Pittston and flows through the Wyoming Valley to Nanticoke, where it leaves the valley by an abrupt northern turn. These breaks of the Susquehanna through the mountains give natural and comparatively easy transportation outlets to the north and west, but the railroads going east and south must surmount the Pocono Mountains, which reach an elevation of about 2,000 feet. The surface elevation decreases gradually from 1,500 feet at Forest City to about 400 feet at Shickshinny. The surface is gently undulating, and both the Lackawanna and Wyoming valleys were originally extremely picturesque, but the landscape is now greatly disfigured by culm heaps and coal breakers, and through the denudation of the forests.

The geographic subdivisions of the northern basin as given by the second geological survey of Pennsylvania are shown in the table facing. These subdivisions have no special geologic, trade, or other significance, and serve merely as useful reference points in the minute descriptions of the anthracite field contained in the reports of that survey.[a] The same remark applies equally to the subdivisions of the other basins as given in the table opposite.

The principal cities are Scranton and Wilkesbarre; the smaller towns are Carbondale, Pittston, Kingston, Plymouth, and Nanticoke.

LOYALSOCK AND MEHOOPANY DIVISION.

Twenty-five miles northwest of the main northern basin there are several small detached coal areas, sometimes known as the western-northern basin, but included by the second geological survey in the northern basin, while the output is included in that of the Wyoming region.

[a] Volume III, Final Summary.

EASTERN-MIDDLE BASIN.

This, the smallest of the geographic divisions, lies about 15 miles south and southwest of the western end of the northern basin, from which it is separated by a mountain range and an intervening valley. Its maximum length is about 26 miles; its greatest width about 10 miles, and the total coal area about 33 square miles.

The surface is a barren, unpicturesque plateau, ranging in elevation from 1,400 to 1,700 feet. The drainage toward the north is through Black and Catawissa creeks, which empty into the North Branch of the Susquehanna; toward the east it is through several small creeks emptying into the Lehigh. There is very slight drainage toward the south and west into the Little Schuylkill River.

There are no large streams in the region, and, as the mountains have been entirely denuded of their timber, there is frequently a scarcity of water for mining operations during dry seasons. The principal town is Hazleton.

SOUTHERN BASIN.

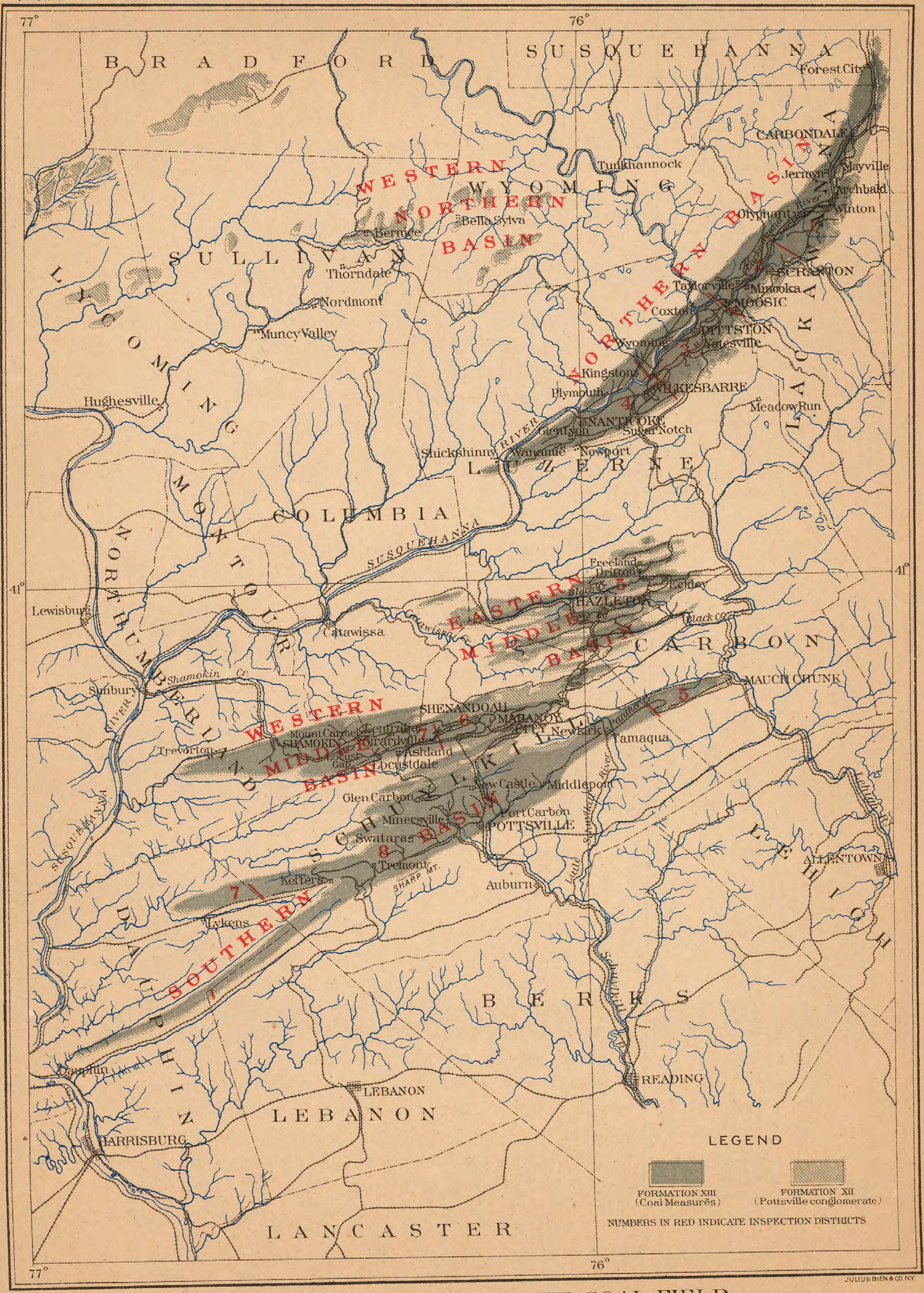
This extends 70 miles east and west from Mauch Chunk, on the Lehigh River, to Dauphin, on the Susquehanna. Near Pottsville it is 8 miles wide, but tapers gradually toward both the east and the west, and in the latter direction it divides into two long narrow basins. It is the largest of the fields and contains 181 square miles. Panther Creek drains the extreme eastern end, but the greater portion of the field drains southward through the Schuylkill and Little Schuylkill. It is bounded on the south by Sharp Mountain, which extends from the Lehigh to the Susquehanna in an almost unbroken line, the mountain crest having an elevation of 1,200 to 1,500 feet.

The surface contour is very broken and rugged, the general elevation varying from 600 to 1,800 feet above tide. The principal towns are Pottsville and Tamaqua.

WESTERN-MIDDLE BASIN.

This lies southwest of and adjoins the eastern-middle basin. It is north of and approximately parallel to the southern basin, which it adjoins for a short distance. It is 36 miles long, 4 to 5 miles wide, with tapering ends, and contains 94 square miles. The elevation of the mountains inclosing the basin is 1,500 to 1,700 feet above tide, while the lowest elevations are 850 feet at Ashland Gap, through which the drainage stream of the eastern or Mahanoy subbasin escapes, and 700 feet at Shamokin Gap, where Shamokin Creek, which drains the western or Shamokin subbasin, breaks through the ridge to the south.

There are two distinct subbasins or divisions of the western-middle basin, the Mahanoy and Shamokin basins, which are about equal in size, depth, and importance. The Mahanoy basin extends from Delano



PENNSYLVANIA ANTHRACITE COAL FIELD

Scale

10 0 10 20 MILES

on the east 25 miles westward to a point 4 miles west of Locust Gap. It is $2\frac{1}{2}$ miles wide near Shenandoah, and about 2,000 feet deep to the base of the Buck Mountain bed. The Shamokin basin extends from a point just east of Centralia 30 miles westward, to the west end of the western-middle basin. It is 3 miles wide near Shamokin and 1,800 feet deep to the base of the Buck Mountain bed.

The western-middle basin is traversed by a number of ridges which are nearly as high as the main mountain ridges inclosing the main basin, thus making the subbasins topographically very rugged and giving them a peculiarly barren appearance. The principal towns are Shenandoah, Mahanoy City, Ashland, Mount Carmel, and Shamokin.

MINE INSPECTION DISTRICTS.

The boundaries of these districts are shown on the map, Pl. VI, where they are designated by numbers in red.

TRADE AND LABOR DISTRICTS.

The lines of division for these two purposes agree and are fairly indicated by the accompanying map (Pl. VI), and by the following table:

Trade and labor districts in Pennsylvania anthracite coal field.

Trade.	Geographic.	Labor district.
Wyoming region	Northern field and Bernice Basin	No. 1
Lehigh region	Eastern middle field and southern field east of Tamaqua.	No. 7
Schuylkill region	Western middle field and southern field west of Tamaqua.	No. 9

The local divisions given in the table on page 62, follow those made by Mr. John H. Jones for convenience in locating the anthracite collieries, and were those used by the second geological survey of Pennsylvania in preparing a map of the anthracite regions in 1886, and for the revision of the same in 1890.

The divisions are, of course, in a sense arbitrary, not being based upon any geologic consideration, but as they are largely identified with the names of the principal towns in the subdivisions, or other local names, they have served the purpose of dividing the regions in such a manner as to afford easy reference on the anthracite map.

PROBABLE EXTENSIONS OF THE ANTHRACITE FIELD.

With periodic regularity the daily newspapers contain accounts of new anthracite discoveries, the favorite districts for such discoveries being the Nescopec Valley, situated between the Wyoming and

Lehigh regions; the territory north of the Wyoming field and between it and the Bernice basin; and the Pocono Mountains north and east of the Lackawanna Valley and between it and the Delaware River.

The geologic features of the region are, however, so marked, and so much prospecting work has been done by the second geological survey of Pennsylvania, and by the large mining corporations, that it is improbable that new fields of any extent will be discovered. It is probable that the limits of the anthracite measures are quite accurately shown on the accompanying map (Pl. VI) and that the boundaries there given can be relied upon as representing the outside limits of the anthracite field.

GEOLOGIC RELATIONS.

The beds of anthracite coal were, according to Lesley, originally bituminous in character; they were deposited at the same time as the bituminous coal of western and central Pennsylvania, and were subsequently changed to their present anthracite character by some process of metamorphism.

STRATIGRAPHY OF THE COAL-BEARING ROCKS.

The Carboniferous formations of Pennsylvania, with the numbers by which they are generally referred to in the second geological survey reports, are the following:

No. 10. Pocono gray sandstone.
No. 11. Mauch Chunk red shale.
No. 12. Pottsville conglomerate.
No. 13. Allegheny River coal measures.
No. 14. Pittsburg (Lower Barren) measures.
No. 15. Monongahela River coal measures.
No. 16. Washington County group.
No. 17. Greene County (Upper Barren) measures.

Formations 10 and 11 are found extensively within the boundaries of the anthracite region, but within the more restricted producing basins now containing coal the second geological survey recognizes but two formations—No. 12, or the Pottsville conglomerate, and No. 13, or the "Coal Measures." In connection with anthracite geology, No. 13, or the "Coal Measures," usually includes beds of sandstones, coal, shale, and fire clay, underlain by Pottsville conglomerate, and included in Nos. 13, 14, 15, and 16 of the bituminous region as tabulated above. No correlation of these bituminous subdivisions with the anthracite measures has yet been worked out, nor is it certain that it ever can be.

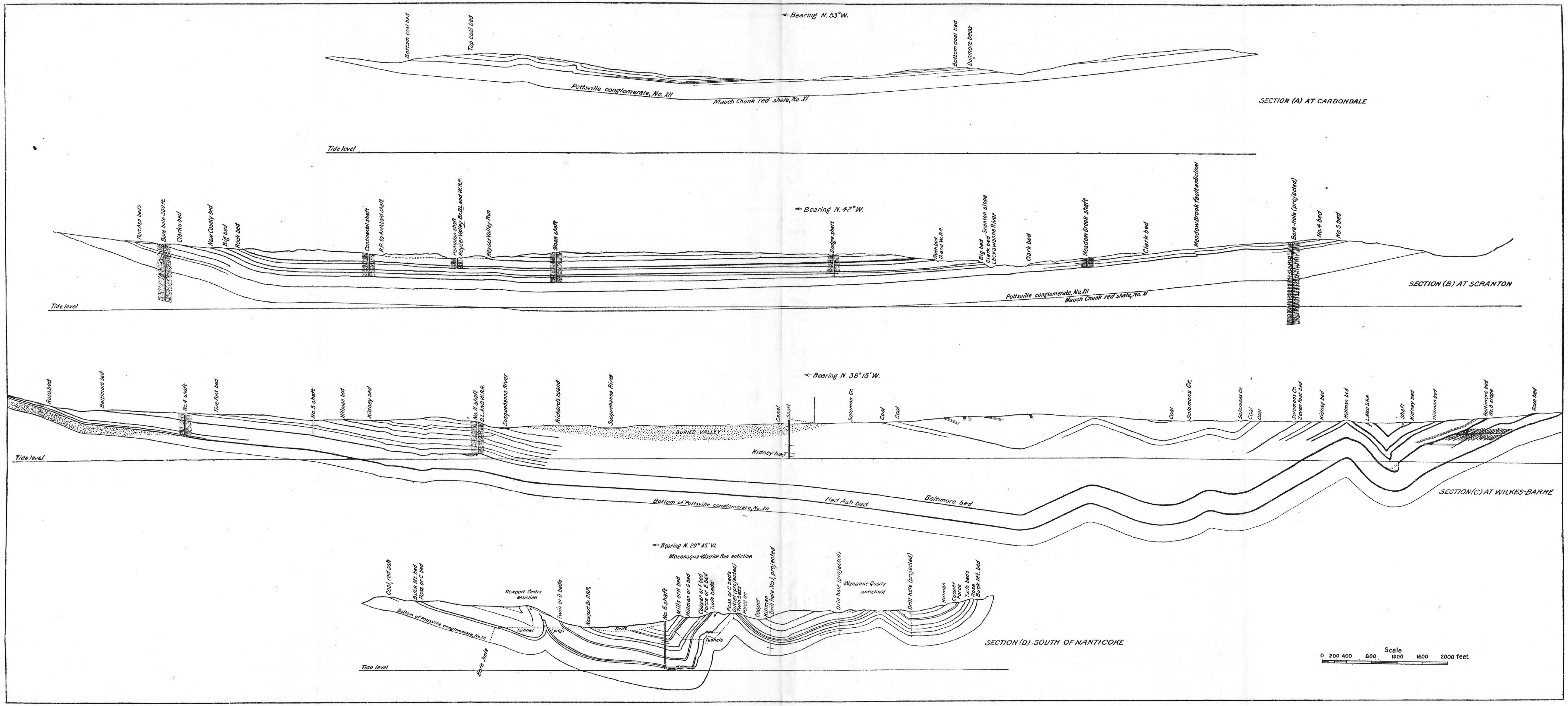
Formation No. 12 consists of beds of gray conglomerate, white, gray and brown sandstones, which are usually coarse and hard, thin beds of carbonaceous slates, and usually one or more thin coal beds, which increase in thickness and value from northeast to southwest, and in the southwestern part of the anthracite field become large, valuable, and workable beds. As a rule, the lower strata of the formation are greenish in color, shading downward into the red of the Mauch Chunk red shale. The central portion of the formation is coarse and hard and forms the crests of the mountain ridges inclosing the coal basins; the upper part is mainly coarse sandstone and finer conglomerates. The valuable Lykens Valley coal beds are mainly in the upper and in the lower portions of the formation.

The upper limit of the Pottsville No. 12 is well defined, and is usually considered to be the base of the Buck Mountain or Red Ash coal bed. The base of No. 12 is less easily determined, and the transition beds between the conglomerate and the underlying Mauch Chunk red shale reach in some places a thickness of 600 feet.

There is a gradual increase in thickness and a change in the character of formation from northeast to southwest. In the extreme northeastern part of the anthracite region, northeast of Scranton, coarse sandstones and fine conglomerates predominate, but toward the southwest the size of the pebbles gradually increases until in some localities they become distinct bowlders. The maximum known thickness of the formation is probably at Kalmia colliery, where it is 1,475 feet thick. The average thickness of the formation throughout the region is about as follows: Loyalsock, 120 feet (?), not definitely determined; northern basin, 225 feet; eastern middle, 300 feet; western middle, 850 feet; southern, 1,200 feet.

It is probable that only a very small part of the Coal Measures originally deposited in this region has escaped erosion. The maximum thicknesses of the portions remaining are as follows: Northern field, 1,800 feet; eastern middle, 700 feet; western middle, 1,000 feet; southern, 2,500 feet. These are maximum measurements and by no means represent the average thickness, which is very hard to estimate on account of the numerous local variations.

The formation has coal beds distributed throughout its whole extent, the beds varying in thickness from mere traces of coal to the Mammoth bed, which has a thickness of 50 to 60 feet over wide areas. In general it may be said that the lower 300 to 500 feet of the Coal Measures up to the top of the Mammoth bed contain the thicker deposits. These coal beds are separated by intervals varying from a few feet to several hundred feet, but a barren interval of over 200 feet is rare. The rocks intervening between the coal beds may be classified as follows: (1) Brown or gray sandstones, varying in texture from soft and shaly up to coarse and hard, and merging into fine



SECTIONS OF THE NORTHERN ANTHRACITE COAL FIELD.

conglomerates, which, in some instances, are so coarse as to be mistaken for the Pottsville conglomerate; (2) shales of various degrees of hardness and varying in color; (3) black, carbonaceous slate or shale; (4) fire clays, frequently, but not always, underlying the coal, and also frequently found apart from the coal beds. The intervals between the same coal beds vary greatly in different basins, and even in different parts of the same basin.

In the northern field different names are given to the same bed in different sections, but in the eastern middle, western middle, and southern basins common names are used, at least for the principal coal beds, which are quite similar in these three districts, so that the measures can be correlated with comparative ease. No successful attempt has yet been made to correlate all of the beds of the northern field with those of the other fields, although the Red Ash, Skidmore, and Baltimore beds of the northern field are generally accepted as being identical with the Buck Mountain, Skidmore, and Mammoth beds, respectively, of the other fields.

Although there are certain features which are more or less common to the important beds throughout a district, their local variations are so marked as to render it impossible, in so condensed a description as the present, to give characteristic features. Descriptions would have to be so generalized that they would probably be misleading.

STRUCTURE OF THE ANTHRACITE BASINS.

A very striking feature of the anthracite coal field is the form of its basins. The coal beds are frequently upturned to the vertical position, and sometimes even overturned. At the upper or northeast end of the northern field the basin slopes in gentle curves, which gradually increase in steepness toward the southwest and west, and at the lower end of the field, in the neighborhood of Glen Lyon, the measures dip steeply and are very much contorted. The general dips in the northern field are much more gentle and uniform than in any of the other fields.

In the eastern-middle field the basins are shallow, but the dips are sharp, being from 30° to 50° and even more.

The basins of the western-middle and southern are deep, with steeply dipping sides, the maximum of depth and steepness being in the southern field.

Throughout all of the fields the steepest dips are, as a rule, toward the north and the more gentle ones toward the south. These characteristics are well shown in the accompanying cross sections of the several fields, Pls. VII–X.

THE COAL.

NUMBER AND EXTENT OF WORKABLE BEDS.

NORTHERN FIELD.

From Forest City to Pittston and from Pittston to Nanticoke, north of the Susquehanna, the maximum dips are 10° to 20°, while between Pittston and Nanticoke, south of the Susquehanna, steeper dips, ranging from 60° to 70°, are found, and near Glen Lyon the measures are overturned and badly broken. There are numerous anticlines and synclines in the measures, which can sometimes be traced on the surface, the synclines being often marked by ridges and the anticlines by valleys.

A marked feature of the northern field is the buried valley of the Susquehanna, extending from Pittston to Nanticoke. This is the bed of a former glacial stream which has cut down into the Coal Measures in places, thus cutting out large areas of the upper coal beds. The valley is now filled with sand, and there are numerous pot holes in it, which add an element of uncertainty and danger to the mining.

The Wyoming-Lackawanna basin is deepest (2,200 feet) midway between Wilkesbarre and Nanticoke. About 4 miles above Pittston, near Lackawanna station, only 100 to 150 feet of the Coal Measures are left, but northeast from here, several miles above Scranton, the Coal Measures sink again to a depth of 700 feet, and then rise and spoon out beyond Forest City.

It is difficult to state the number of workable beds, as beds are now being worked in the upper end of the Lackawanna Valley which a very few years ago were neglected and considered unworkable. The splitting of a large coal bed into several smaller beds, which divide and are sometimes separated by as much as 200 feet of rock, renders it impossible to correlate beds in different parts of the field until continuous sections can be made by means of actual mine workings. As the result of measurements of 891 sections by the second geological survey of Pennsylvania, 81.8 per cent of the total coal in the Wyoming basin is or may be considered marketable coal, the remaining 18.2 per cent being interbedded slate, shale, and other refuse. The deposits in this section are particularly free from refuse, and the comparative freedom of this section from plication and folding gives a high percentage of marketable coal.

EASTERN-MIDDLE FIELD.

The structure of this field is simple, consisting of a succession of anticlines, usually with broad flat crests and shallow intervening basins only about 500 to 600 feet deep, the sides dipping 10° to 40°. This gives a large extent of outcrop, and the comparative shallowness of the basins has been very favorable to mining, so that the field has been extensively developed and its structure quite thoroughly determined. The Mammoth, Buck Mountain, Primrose, Parlor, Portland, and Gamma beds vary in thickness in different localities. The second geological survey of Pennsylvania estimated that from 75 to 77 per cent of the total thickness of coal was marketable.

SOUTHERN FIELD.

This field consists of a number of connected basins which grow gradually deeper from north to south, culminating along the foot of Sharp Mountain in very deep, highly upturned, and greatly contorted measures. The Pottsville conglomerate in this region is very thick, ranging from 1,100 to 1,475 feet. It is made up of coarse materials, and contains a number of valuable coal beds, especially at the western end. At the point where the main field subdivides into the two westwardly extending basins there are six Lykens Valley beds in the conglomerate, each 3 to 10 feet thick. The Coal Measures proper are at least 2,500 feet thick, and 20 different coal beds have been worked. From measurements of 275 sections the second geological survey estimated 72 per cent of the coal as marketable.

WESTERN-MIDDLE FIELD.

In this field the beds incline steeply, the average dip being 35 to 40 degrees. There has been much folding, sliding, and shifting of strata, which has crushed the coal in many places and mixed with it slate and bony coal partings. The Coal Measures are 1,200 feet thick, and contain from 10 to 12 different beds, many of them of great thickness and with comparatively small intervening barren intervals. The Lykens Valley beds are also found in the conglomerate, or No. 12, and toward the western end of the field these beds are mined; 1,144 sections throughout the field give 23 per cent of refuse in the coal, but it is not safe to estimate more than 75 per cent of the original deposit as marketable coal.

ORIGINAL CONTENTS OF COAL FIELD.

The sheet of bore-hole sections in Appendix 1 to the report of the Coal Waste Commission shows the thicknesses of the several coal beds throughout the anthracite field, and upon this Mr. D. W. Smith based his estimates of the content of coal in the anthracite coal field before mining began. In regard to this section, Mr. Smith says:[a]

Probably the highest workable coal bed is the Brewery bed, found in the Southern field, some 1,900 feet above the Mammoth bed. The number of coal beds and the thickness of each that perhaps once existed above the Brewery bed we do not know. A columnar section in the neighborhood of Pottsville would show some 20

[a] Report of Coal Waste Commission, Harrisburg, Pa., page 56.

workable coal beds between and including the Brewery and Buck Mountain beds, with an estimated total average thickness of 108 feet, some 72 per cent, or 78 feet, of which is estimated to be workable coal.

At Tamaqua a fewer number of beds have an aggregate thickness of 109 feet, of which 78 feet is workable coal.

At Shamokin the section from the Tracy bed (the sixth below the Brewery) down shows 70 feet, of which 77 per cent, or 54 feet, is workable coal.

At Shenandoah from the Little Tracy down, the section shows 113 feet, or 87 feet of workable coal.

In the eastern-middle field all but one or two of the beds above the Mammoth have been removed by erosion.

In the Northern field probably the highest existing workable bed is the New bed, only some 600 feet above the Bennett or Mammoth.

At Wilkesbarre the section shows some 11 workable beds, with an aggregate thickness of 85 feet, of which 81.8 per cent, or 69 feet, is estimated as workable coal.

A consideration of these columnar sections would indicate that the original coal field had in the neighborhood of the existing fields an average thickness of probably not less than 75 feet of coal in workable beds. If we estimate 1,900 tons per foot-acre, 1 acre 75 feet thick would contain 152,500 tons, say, 150,000 tons, and 1 square mile 640 times this, or 96,000,000 tons.

Mr. Smith estimates the original contents of the anthracite coal fields as follows:[a]

Estimate of original content of Pennsylvania anthracite coal field.

BY FIELDS.

	Area lowest workable coal bed.	Probable original contents.
	Sq. miles.	*Tons.*
Northern	176.29	5,697,380,784
Eastern-middle	32.72	602,491,447
Western-middle	94.04	4,009,564,831
Southern	181.16	9,198,435,263
Total	484.21	19,507,872,325

BY REGIONS.

	Area lowest workable coal bed.	Probable original contents.
	Sq. miles.	*Tons.*
Wyoming	176.29	5,697,380,784
Lehigh	45.25	1,635,488,578
Schuylkill	262.67	12,175,002,963
Total	484.21	19,507,872,325

[a] Penna. Geological Survey, Summary Final Report, Vol. III, Part 1, page 2151.

What part of the original deposit this represents before glaciation took place we have no way of telling, and all estimates along this line are purely speculative. Mr. Smith says that the amount of coal in the ground when mining began represented not more than 6 per cent, probably about 2 per cent, and possibly only 1 per cent, of the original coal deposit before erosion took place.

COMPOSITION OF PENNSYLVANIA ANTHRACITE.

The following table, taken from the annual report of the Pennsylvania geological survey for 1885, gives the mean results of about 30 analyses of coal from the different sections of the anthracite region. The analyses were made by Mr McCreath and the samples were collected from lots of from 100 to 200 tons which were ready for shipment to market.

Average composition of Pennsylvania anthracite.

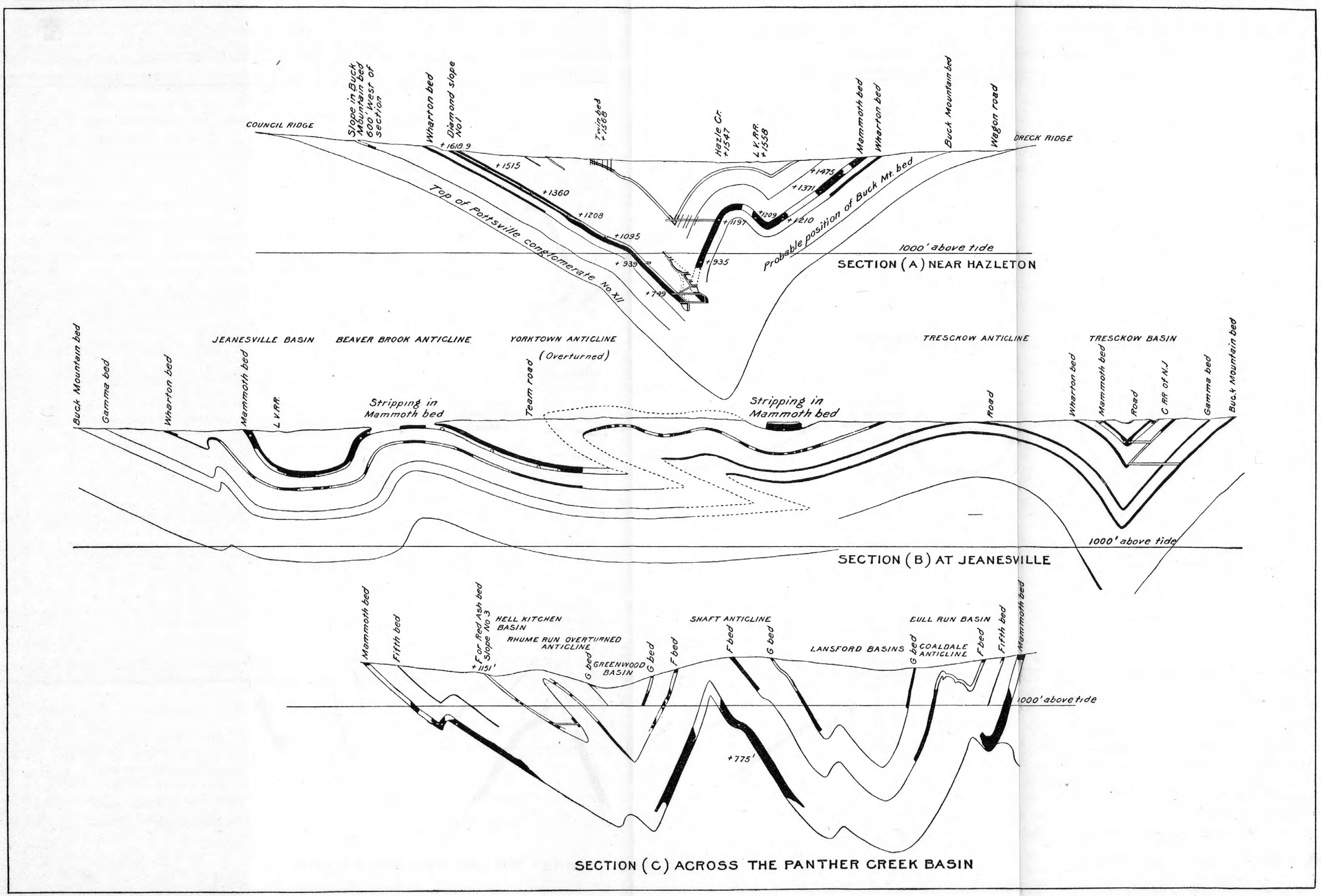
Number of specimens.	Name of coal bed.	Name of coal field.	Water.	Volatile matter.	Fixed carbon.	Sulphur.	Ash.	Total.	Specific gravity.	Percentage of fuel constituents.		
										Fixed carbon.	Volatile combustible matter.	Carbon ratio. C. / V. H.—C.
3	Wharton	Eastern-middle..	3.713	3.080	86.404	.585	6.218	100	1.620	96.56	3.44	28.07
5	Mammoth	.....do	4.119	3.084	86.379	.496	5.922	100	1.617	96.55	3.45	27.99
2	Primrose	Western-middle.	3.541	3.716	81.590	.499	10.654	100	1.654	95.64	4.36	21.93
5	Mammoth	.....do	3.163	3.717	81.143	.899	11.078	100	1.657	95.62	4.38	21.83
2	Primrose[a]	Southern	3.008	4.125	87.982	.506	4.379	100	1.584	95.52	4.48	21.32
2	Buck Mountain ..	Western-middle.	3.042	3.949	82.662	.462	9.885	100	1.667	95.44	4.56	20.93
1	Seven Foot.	.....do	3.410	3.978	80.868	.512	11.232	100	1.651	95.31	4.69	20.32
7	Mammoth	Southern	3.087	4.275	83.813	.641	8.184	100	1.631	95.15	4.85	19.62
3	.....do	Northern	3.421	4.381	83.268	.727	8.203	100	1.575	95.00	5.00	19.00
	B. coal bed[b]	Loyalsock	1.295	8.100	83.344	1.031	6.230	100	.....	91.14	8.86	10.29

[a] Called Red Ash bed in the Panther Creek basin.

[b] This coal, according to the classification referred to below, would be called semianthracite, on account of its percentages of volatile matter and fixed carbon The percentage of volatile matter is not as great, however, as that contained in many of the coals from the Shamokin and Lykens Valley districts, with which the Loyalsock coal favorably compares The Shamokin and Lykens Valley coals are called anthracites by the trade, and on this basis the trade must consider Loyalsock or Bernice coal an anthracite.

It is well known that the percentage of ash increases with the decrease in the market size of prepared coal.

Owing to the demands of purchasers, anthracite coal is now cleaned much more perfectly than it was some years ago, and a similarly comprehensive series of tests would undoubtedly show the average coal shipped to market to be purer than is given by the above table. Such comprehensive tests are, however, not available.



SECTIONS OF THE ANTHRACITE COAL BASINS IN THE LEHIGH REGION.

The following table gives the composition of the different sizes of coal as exhibited by the Lehigh Valley Coal Company at the Paris and Pan-American expositions.

Composition of different sizes of Pennsylvania anthracite.

	Fixed carbon.	Volatile matter.	Water.	Ash.
Broken	88.3	5.75	.8	5.15
Egg	88.3	5.75	.8	5.15
Stove	88.65	5.15	.95	5.25
Nut	87.325	5.65	.825	6.2
Pea	86.925	6.315	.935	5.825
Buckwheat	85.725	6.16	.84	7.275
Rice	83.9	6.585	.765	8.750
Birdseye	85.775	6.5	.700	9.025

The following table gives the results of a number of analyses made in a commercial laboratory in Scranton upon samples of coal coming from various parts of the Lackawanna and Wyoming regions.

Analyses of Pennsylvania anthracite.

Name of coal or locality.	Moisture.	Volatile combustible matter.	Fixed carbon.	Ash.	Sulphur.	Fuel ratio.
Hillman bed	1.492	14.982	76.623	6.429	0.474	5.11
Baltimore bed	1.596	8.142	84.308	5.561	.033	10.35
Diamond bed	2.788	7.698	74.780	14.071	.663	9.71
Red Ash bed (top)	2.168	6.846	84.176	6.317	.493	12.30
Red Ash bed (lower part)	1.976	6.098	87.799	3.284	.843	14.39
Ross bed	1.455	7.102	84.499	6.737	.207	11.90
Wilkesbarre	1.367	3.224	86.939	8.013	.457	27
Do	1.326	8.435	70.114	20.125	....	8.32
Mine near Minooka	2.317	7.629	70.907	19.147	....	9.29
Wilkesbarre	5.090	8.274	79.974	5.790	.872	9.67
Do	1.503	6.892	83.177	7.943	.485	11.92
Do	2.081	5.069	86.364	6.097	.389	17.03
Near Miners Mill	4.179	5.286	84.980	4.936	.619	16.09
Wilkesbarre	1.732	3.419	88.609	6.240	....	21.87
D. and H	1.732	4.156	88.489	5.014	.609	21.32
Do	1.690	4.055	79.921	13.620	.714	19.68

SPECIFIC GRAVITY OF ANTHRACITE.

Experiments carried on by Messrs. Coxe Bros. & Co. upon coal from the Drifton Colliery gave the specific gravity of 1.55 for pure anthracite. The average specific gravity obtained by Mr. McCreath in connection with the 30 analyses noted above was 1.575. The specific gravity of the eight samples from the eastern-middle field was 1.614; of the ten from the western-middle field was 1.658, and of the nine from the Panther Creek basin of the southern field was 1.6307. A number of specific-gravity determinations of the Lykens Valley coal from the western part of the southern field, by Mr. John R. Hoffman, of the Philadelphia and Reading Coal and Iron Company, give a variation of 1.42 to 1.50, with an average of 1.44. A series of tests carried on by the Pennsylvania Railroad Company's coal department gave the average specific gravity of the coal as 1.4784 and the average weight per cubic foot as 92.50. The following table, taken from the Coal and Metal Miners' Pocket Book, is of interest in this connection:

Weight per cubic foot of Susquehanna Coal Company's white-ash anthracite coal.

Size.	Size of mesh.		Weight per cubic foot.	Cubic feet from 1 cubic foot solid.
	Over.	Through.		
	Inches.	*Inches.*	*Pounds.*	
Lump	$4\frac{1}{2}$ to 9	....	57	1.614
Broken	$2\frac{3}{8}$ to $2\frac{7}{8}$	$3\frac{1}{4}$ to $4\frac{1}{2}$	53	1.755
Egg	$1\frac{3}{4}$ to $2\frac{1}{4}$	$2\frac{3}{8}$ to $2\frac{7}{8}$	52	1.769
Large stove	$1\frac{1}{4}$ to $1\frac{7}{8}$	$1\frac{3}{4}$ to $2\frac{1}{4}$	$51\frac{1}{2}$	1.787
Small stove	1 to $1\frac{1}{4}$	$1\frac{1}{4}$ to $1\frac{1}{2}$	$51\frac{1}{4}$	1.795
Chestnut	$\frac{5}{8}$ to $\frac{3}{4}$	1 to $1\frac{1}{4}$	51	1.804
Pea	$\frac{3}{8}$ to $\frac{5}{8}$	$\frac{5}{8}$ to $\frac{7}{8}$	$50\frac{3}{4}$	1.813
No. 1 buckwheat	$\frac{3}{16}$ to $\frac{3}{8}$	$\frac{3}{8}$ to $\frac{5}{8}$	$50\frac{3}{4}$	1.813
No. 2 buckwheat	....	$\frac{3}{16}$ to $\frac{3}{8}$	$50\frac{3}{4}$	1.813

DEVELOPMENT OF THE ANTHRACITE COAL FIELD.

HISTORY.

From the fact that in each of the divisions of the anthracite coal field there are numerous outcropping beds, and since the region is traversed by streams, many of which cut across the measures and expose the beds of coal, it is probable that the existence of coal was known to the Indians prior to the advent of the whites.

The first authentic date in connection with anthracite coal is 1762, when Parshall Terry and a company of Connecticut pioneers found coal at the mouth of Mill Creek, on the banks of the Susquehanna, near the site of the present city of Wilkesbarre. In 1769 Obadiah Core, a blacksmith, used anthracite for fuel in his forge. The presence of coal in the Mahanoy and Shamokin basin of the Schuylkill region was known in 1770, but the beds were not developed until 1834. In 1775, the proprietary government of Pennsylvania had coal floated down the Susquehanna from Wilkesbarre to Harris Ferry (Harrisburg), whence it was hauled by wagon to the arsenal at Carlisle for use in the manufacture of munitions of war. Similar shipments were made annually during the Revolutionary war. In 1788 Jesse Fell used this coal in his nailery.

In 1791 coal was discovered near Mauch Chunk by Philip Ginter, who, according to tradition, on returning home at night kicked a black stone in his path, which proved to be anthracite. The Lehigh Coal Mine Company was formed in 1792, and secured a large tract of coal land, and in 1793 a road was built to the Lehigh River above Mauch Chunk.

Coal was used locally by blacksmiths immediately after each of the above discoveries, and numerous attempts were made to float coal-laden arks down the Lehigh and Susquehanna, but people would not believe that the black stones would burn, and no progress was made for some years in the development of a coal trade.

Oliver Evans burned anthracite in a grate in Philadelphia in 1802. So also did Frederick Groff, chief of the water company in Philadelphia in 1802.

In 1805–6 John and Abijah Smith, from Derby, Conn., settled in Plymouth, Pa., bought coal lands, and immediately began shipping coal by arks to points along the lower Susquehanna River. Fifty-five tons were shipped in 1807 to Columbia, Pa., and thereafter 400 to 500 tons yearly to points on the lower Susquehanna and to Baltimore, where $10 per ton was received, and to New York, where $12 was the price. It was necessary to create a demand for anthracite coal and to instruct people in its use, so the Smith brothers accompanied their arks and took with them suitable grates, which were set up in public houses to demonstrate the use and value of this fuel.

In 1804 coal was discovered at Carbondale by Samuel Preston; in 1814 William and Maurice Wurtz began its development, and in 1815 they succeeded in sending an ark load to Philadelphia by the Lackawaxen and Delaware rivers, but this experiment was not repeated until 1823.

Reports of the anthracite coal trade are usually begun with the year 1820, when 365 tons of coal were shipped to Philadelphia from the Lehigh region by the Lehigh Coal and Navigation Company, but the dates given above show that the starting point should go back to 1807, and that credit should be given to the Smith brothers, of Plymouth, who carried on a successful trade in coal for thirteen years prior to the usual time of beginning the record.

Between 1820 and 1823 the trade from the Lehigh region was firmly established, and about 1825 the Schuylkill region was opened up upon the completion of water communication with Philadelphia by the Schuylkill Navigation Company.

Between 1823 and 1825 the Delaware and Hudson Canal Company was incorporated, and in 1829 began to ship coal from Carbondale by the canal and the gravity railroad.

From this time on the trade rapidly increased, canals and gravity roads were multiplied, only to be replaced by locomotives soon after the advent of the locomotive in America. One of the first locomotives used in America was the Stourbridge Lion, imported from England for use near Honesdale, Pa. The rate of development is shown by noting the output at the end of each twenty years as given in the following chronological table, which is based upon a table given by Mr. William Griffith in the Bond Record for February, 1896, supplemented by other dates taken from The Coal Trade for 1900, and from a chronology of coal-mining which appeared in one of the bulletins of the mining department of the Pennsylvania State College.

1754.—That portion of Pennsylvania including the Wyoming and Lackawanna coal fields purchased by the Susquehanna Company from the Five Nations.

1758.—The same anthracite territory included in the purchase of 1754 was also included in the purchase made by the proprietary government of Pennsylvania from the Indian nations.

1760.—Anthracite discovered in Rhode Island.

1762.—Anthracite discovered in Wyoming Valley by Connecticut settlers.

1768.—Anthracite used in the Wyoming Valley, Pennsylvania.

1769.—Obadiah Gore first burned anthracite in his smith forge.

1775.—Coal mined on banks of Susquehanna, near site of Pittston.

1776–1780.—Coal mined on banks of Susquehanna, near Wilkesbarre, and shipped to Carlisle, Pa.

1788.—Nails made with anthracite by Judge Jesse Fell, of Wilkesbarre, Pa.

1790.—Coal known to be plentiful in Schuylkill, but not much used.

1791.—Coal discovered on Mauch Chunk Mountain by Philip Ginter.

1792.—Lehigh Coal Mining Company organized.

1795.—Blacksmith named Whetstone used anthracite in Schuylkill region.

1799.—Coal discovered at Carbondale.

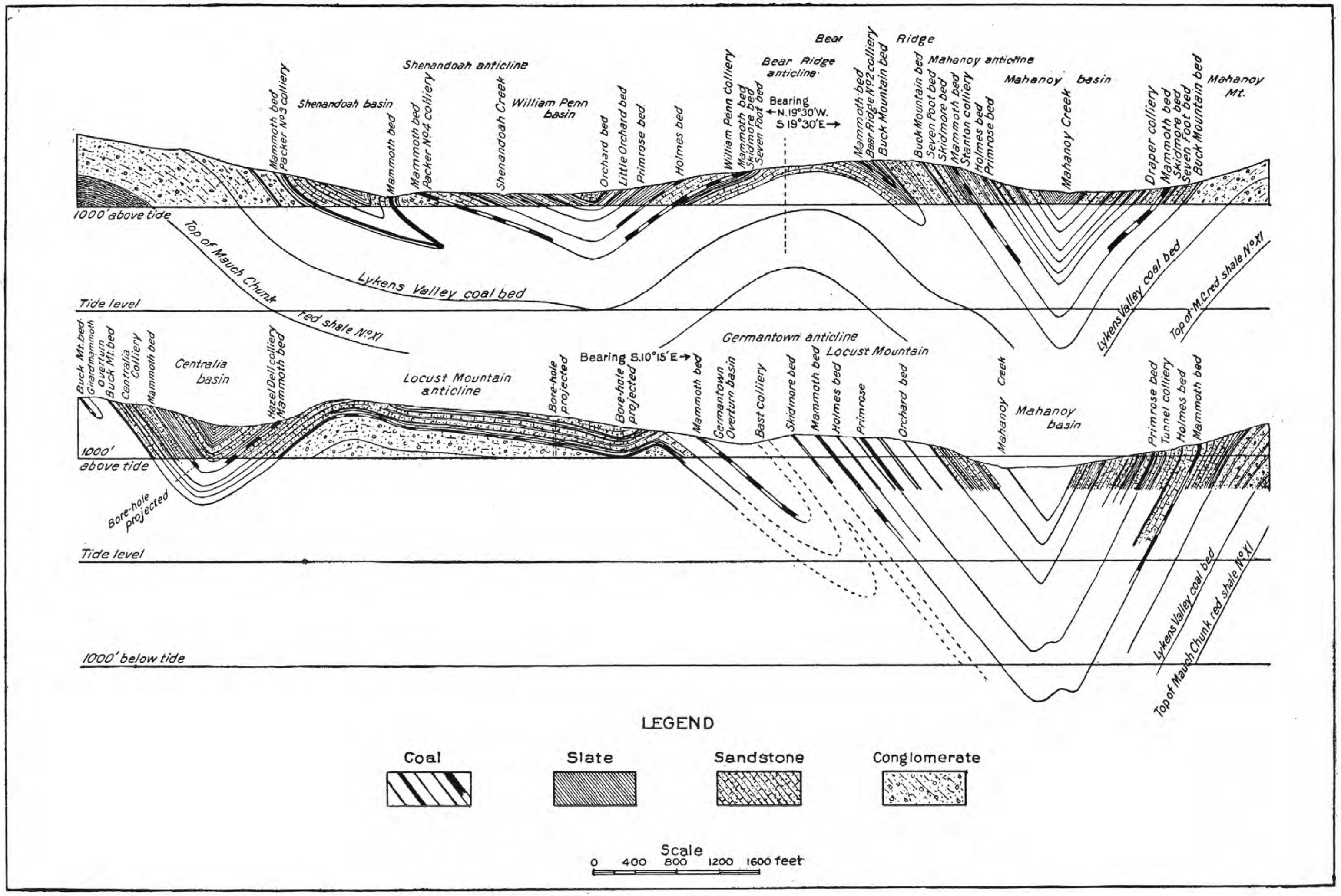
1800.—Coal shipped to Philadelphia from Pottsville by William Morris.

1802–03.—Two ark loads sent to Philadelphia by Lehigh Coal Mine Company, used to gravel the walks. Anthracite first burned in a grate in Philadelphia.

1806.—Another ark load of coal sent to Philadelphia and rejected.

1807.—Abijah Smith & Co. began mining at Plymouth, in Wyoming Valley; shipped 55 tons.

1808.—Judge Fell burned anthracite in a grate in Wilkesbarre, Pa. Abijah Smith & Co. shipped several ark loads to Columbia and other points.



SECTIONS OF THE WESTERN-MIDDLE ANTHRACITE COAL BASIN.

1812.—Anthracite first successfully used in an iron furnace at Philadelphia. Coal shipped to New York and sold at $15 per ton. Nine wagon loads of coal sent to Philadelphia from Pottsville by Colonel Shoemaker and most of it given away.

1813.—Number of small mines opened in Schuylkill region, and coal sold locally at $3.50 per ton.

1814–15.—Coal mined at Carbondale and shipped via Lackawaxen and Delaware Canal to Philadelphia.

1815.—Schuylkill Navigation Company organized.

1817.—Coal the chief article of export and the local fuel of Wyoming region.

1818.—Lehigh Navigation Company and Lehigh Coal Company organized and merged into Lehigh Coal and Navigation Company.

1820.—About 12,000 tons shipped to date from Wyoming Valley. Lehigh Coal and Navigation Company began mining and shipping; price, Philadelphia, $8.40 per ton.

1823.—First cargo of anthracite shipped around Cape Cod to Boston.

1823–1825.—Delaware and Hudson Canal Company organized.

1825.—Schuylkill Canal completed, Philadelphia to Mount Carbon.

1826.—Mauch Chunk Switchback Railroad completed.

1828.—First railroad built by Delaware and Hudson Canal Company.

1829.—Baltimore Coal Company organized to mine coal at Wilkesbarre. Delaware and Hudson Canal Company began shipping from Carbondale.

1831.—North Branch Canal completed to Nanticoke. Morris Canal opened to Newark. Nesquehoning Railroad built. Dr. Geissenhainer applied for a patent for making iron with anthracite.

1832.—Shamokin division Northern Central Railway opened. Little Schuylkill Railroad began shipping from Tamaqua.

1833.—Delaware division Pennsylvania Canal opened.

1834.—Mahanoy and Shamokin basins developed. North Branch Canal completed to Lackawanna River.

1836.—Franklin Institute, of Philadelphia, offered a prize to the one who should first make over 20 tons of pig iron from anthracite (not awarded). Morris Canal opened to Jersey City.

1837.—Lehigh navigation to White Haven opened. First shipments of coal from Beaver Meadow region.

1838.—First shipments of coal from Hazleton region. Anthracite used in blast furnace at Mauch Chunk and Pottsville.

1839.—Shipments from Shamokin and Lykens Valley regions (westward) began. Summit Branch Railroad opened.

1840.—Quakake Railroad opened; extended to Mount Carmel 1862.

1841.—Reading Railroad carried 850 tons of coal.

1842.—Philadelphia and Reading Railroad began carrying coal to Philadelphia.

1843.—Lehigh Coal and Navigation Company's Railroad from White Haven completed.

1846.—Shipments from Wyoming region via Lehigh and Susquehanna Railroad and Lehigh Canal.

1849.—Washington Coal Company, organized 1838, merged into Pennsylvania Coal Company.

1850.—Pennsylvania Coal Company began business.

1851.—Delaware, Lackawanna and Western Railroad built from Scranton to Great Bend.

1852.—Central Railroad of New Jersey opened to Easton. Delaware, Lackawanna and Western Railroad began breaking coal into sizes for market, followed by Delaware and Hudson.

1854.—Lehigh Valley Railroad building; in 1855 transported coal.

1855.—Anthracite leads charcoal in the manufacture of pig iron.

1856.—Delaware, Lackawanna and Western Railroad completed to Delaware Water Gap. Shipments began from Trevorton.

1857.—Belvidere-Delaware Railroad began transporting coal. North Pennsylvania Railroad opened.

1858.—Mining began in McCauley Mountain region. Lackawanna and Bloomsburg Railroad opened; leased to Delaware, Lackawanna and Western Railroad 1873.

1866.—Lehigh and Susquehanna Railroad opened to Scranton.

1867.—Lehigh Valley Railroad opened to Pittston Junction.

1868.—Pennsylvania Railroad began carrying coal. Lehigh and Susquehanna Railroad completed to Easton.

1869.—Wilkesbarre Coal and Iron Company began business. Pennsylvania and New York Railroad opened to Waverly.

1870.—Sunbury, Hazleton and Wilkesbarre Railway opened; leased by Pennsylvania Railroad 1878. Nesquehoning Valley Railroad and Panther Creek Tunnel opened. Erie Railway began mining and shipping coal.

1871.—Lehigh and Susquehanna Railroad leased to Central Railroad of New Jersey. Strike of miners in Wyoming region. Erie Railroad began mining and shipping coal.

1872.—Lehigh Valley Railroad leased Morris Canal.

1873.—Philadelphia and Reading Coal and Iron Company began mining and shipping coal.

1874.—Wilkesbarre Coal and Iron Company merged into Lehigh and Wilkesbarre Coal Company.

1875.—Coke leads anthracite in the manufacture of pig iron.

1876.—During the last few years the large companies secured control of trade by purchasing collieries, etc. February, Anthracite Board of Control formed to regulate the trade.

1878.—Sunbury, Hazleton and Wilkesbarre Railroad leased by Pennsylvania Railroad.

1878–79.—Period of the auction sales of coal.

1879.—Philadelphia and Reading Railroad leased Bound Brook Road. Lehigh and Wilkesbarre Coal Company and Lehigh Coal and Navigation Company absorbed by Central Railroad of New Jersey. Stove coal sold at auction in September for $2.36 per ton.

1882.—North and West Branch Railroad opened November 23.

1883.—Philadelphia and Reading leased Central Railroad of New Jersey June 1.

1884.—Thomas Dickson died; Erie and Wyoming Valley Railroad built, and North and West Branch Pennsylvania Railroad extended to Wilkesbarre.

1885.—Pennsylvania mine law put in force. Pennsylvania Coal Company's gravity railroad to Hawley abandoned.

1886.—Jersey Central arranged to resume independence on January 1, 1887.

1887.—Important development of lake and Western trade.

1889.—Poughkeepsie Bridge route opened.

1888.—A "banner year." High prices and large tonnage.

1890.—New York, Ontario and Western line to Scranton opened.

1891.—Coxe Brothers' road (D. S. & S.) began operations.

1892.—"Reading deal" organized by A. A. McLeod in February.

1893.—Combination broken. Port Reading began business.

1894.—New York, Susquehanna and Western line to Wilkesbarre opened.

1895.—Last formal meeting of the "sales agents" held.

1896.—Last meeting of presidents held January 23 and percentages adopted.

1897.—E. P. Wilbur resigned presidency of the Lehigh Valley Railroad.

1898.—New York, Susquehanna and Western leased to Erie. Delaware and Hudson Canal abandoned. New York, Wyoming and Western Railroad organized.

1899.—Change in Lackawanna; Samuel Sloan succeeded by W. H. Truesdale after thirty years' control. Temple Iron Company absorbed certain individual collieries. Delaware Valley and Kingston Railroad incorporated.

1900.—Large numbers of individual collieries bought up by railroads.

1901.—Pennsylvania Coal Company sold to J. P. Morgan and then to Erie Railroad. Delaware Valley and Kingston Railroad abandoned. Central Railroad of New Jersey leased by Philadelphia and Reading.

METHOD OF MINING.

STRIPPINGS.

In each of the anthracite fields there are a number of places where the coal near the outcrops of the seams has not been weathered or changed to any extent, and where the conditions are favorable for open mining or stripping. In such cases the overburden of soil or rock is stripped off by hand labor, by steam shovels, or by wire-rope tramways or buckets, and when this overburden has been removed the coal is quarried out and either hauled by inclines to the surface from the level of the strippings, or, in some cases, when the strippings communicate with underground workings, and where it is impracticable to transport the coal from the strippings over the surface to the breaker, the coal may be taken down a breast of the underground workings and hauled underground to the shaft or slope. The depth of surface that can be profitably removed depends upon circumstances. The second geological survey of Pennsylvania estimates 2 to 3 cubic yards in depth of surface for every cubic yard of coal where there is a loose soil for the overburden.

Stripping is carried on mainly in the Lehigh and Schuylkill region, where the Mammoth and other thick beds occur and where the conditions are particularly favorable for such mining.

CLOSED WORK.

The room and pillar system of mining is the one universally used for the underground mining of the anthracite regions, though, owing to the character of the deposits, some of the local adaptations differ quite widely from the typical room and pillar method as carried out in flat bituminous coal beds.

The mines are opened by drifts and tunnels, where the position of the outcrop and the surface contour render this possible.

The term "drift," as here used, is given its usual significance in the anthracite field—that is, an opening driven from daylight in the coal and along the strike, with only sufficient inclination to provide for drainage. A tunnel is an opening driven from daylight across the measures until the coal is intersected.

Slopes and shafts are, however, the prevailing form of opening, the former being driven in the coal from the outcrop, and the latter being always vertical and rectangular, and usually placed so as to cut the coal bed at the lowest possible elevation on the property to be mined out through the shaft in question. When the shaft can not be placed so as to reach the lowest point of the deposit, the coal below the level of the shaft bottom is reached by means of inside blind shafts, or inside slopes, driven from the shaft bottom level.

The shafts have usually three or five compartments, one for the pump way and ladder way, and two or four for hoisting. When there are four hoist ways two of these are for hoisting from the deeper seams cut by the shaft, and two from the upper seams. A common size of the hoisting compartments is 7 feet 6 inches by 12 feet, or 12 feet 6 inches, the length of the shaft, of course, depending upon the number of compartments. Some of the deepest shafts in the anthracite regions are near Wilkesbarre and Nanticoke, in the Wyoming field, where there are a number between 1,000 and 1,100 feet deep. About Pottsville and Shenandoah there are also several shafts of about the same depth. Both single and double track slopes are used.

From the bottom of a shaft or slope a gangway and a parallel air way are driven each way from the shaft or slope and along the strike of the bed. Off of these the rooms or breasts are turned, either at right angle or obliquely to the gangway, the angle of turning depending upon the inclination of the seam and being determined entirely by haulage conditions, since there is no cleat in the coal. Very rarely is the deposit flat enough to permit of turning breast off from both sides of a gangway.

The great irregularity of the measures, as illustrated in the cross sections, Pls. VII, VIII, IX, X, renders it impossible to carry out the same regular and systematic methods of exploitation, which can be used in the very regular flat bituminous seams of western and central Pennsylvania. The sudden changes in the dip in a mine, often from a flat deposit to a perpendicular, or even an overturned one, render imperative the adoption of an elastic system of working.

WAGON OR ROAD BREASTS.

When the pitch is slight, say from 3° to 10°, the breasts are turned off at such an angle with the gangway that the inclination of the track in the breast will be such that the car can be taken to the face by a mule and run out of the breast by gravity (fig. 8). When the pitch becomes too steep, say above 10°, the breasts are turned off at right angles to the gangway. The pitches given here as limiting the several methods of turning off breasts are of course given in general terms, and as near to an average as it is possible to come, but they can not be taken as absolutely fixed limits.

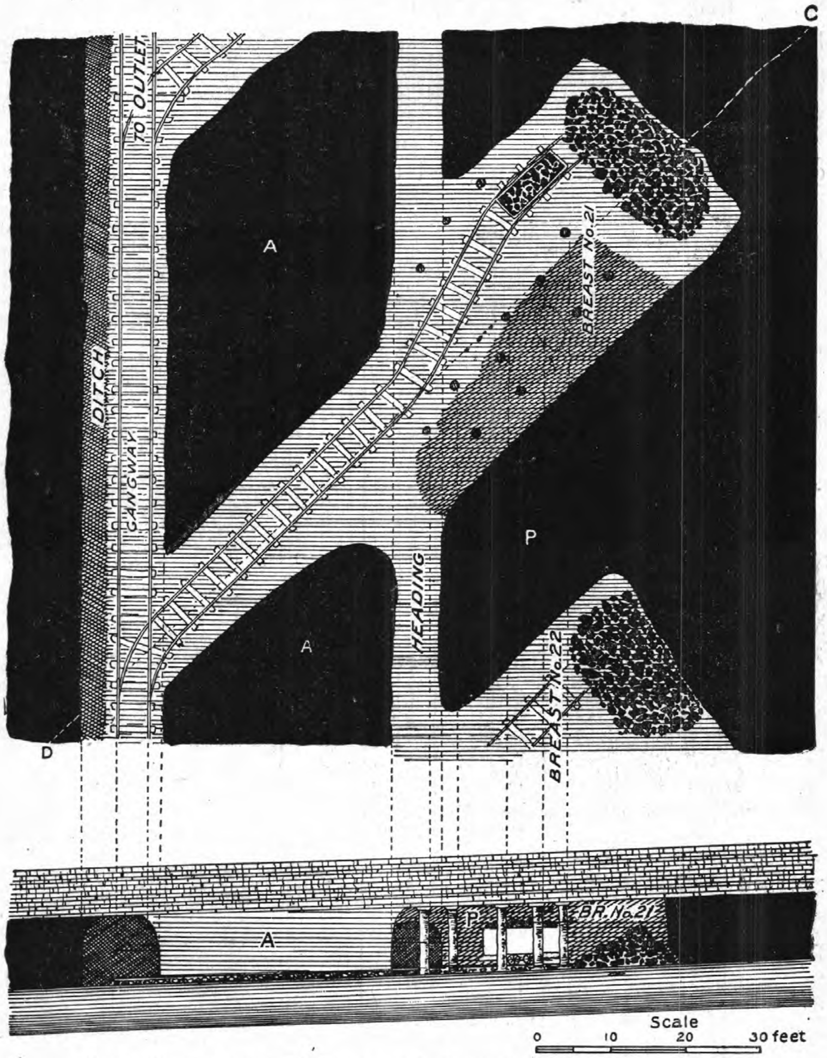
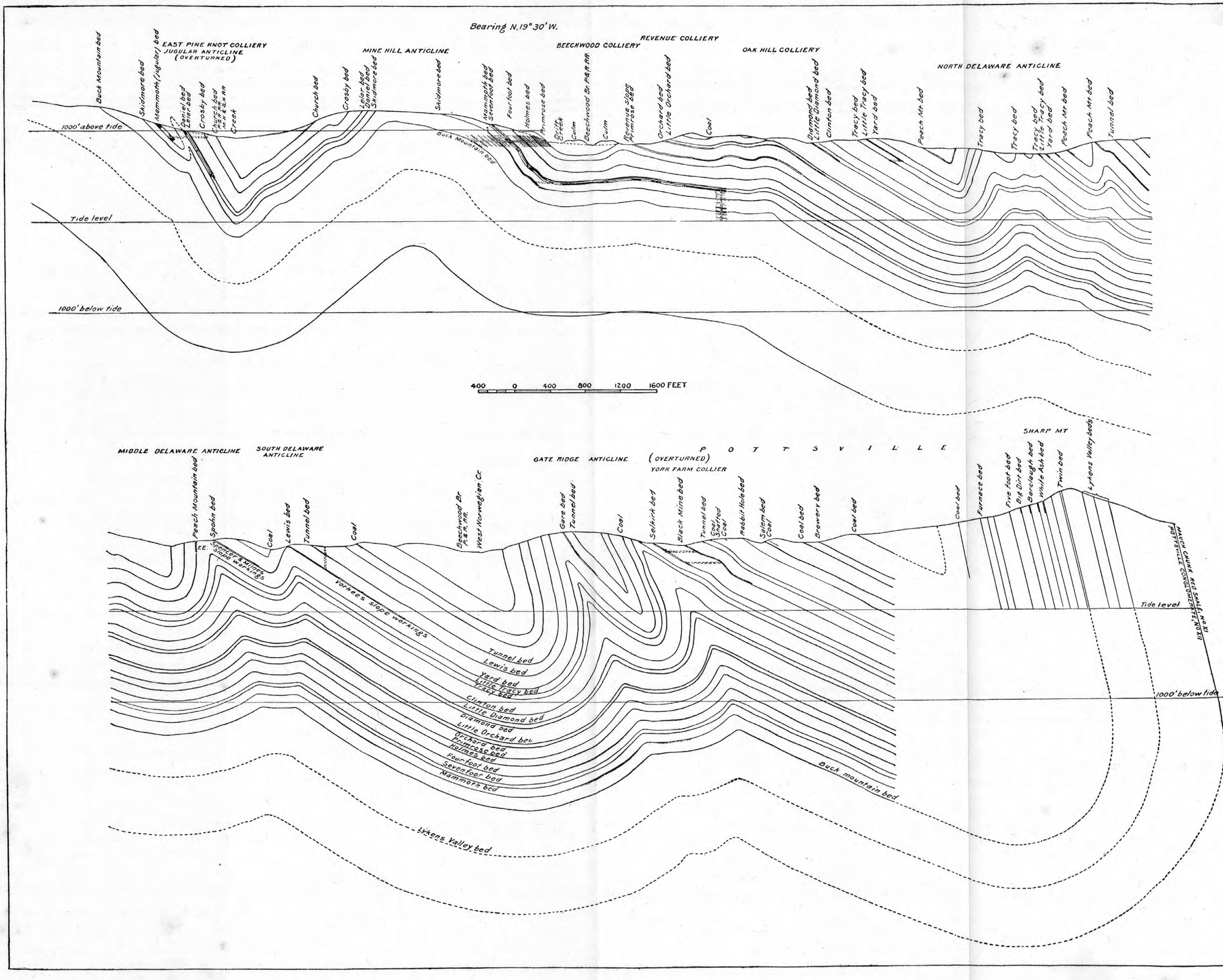


FIG. 8.—Wagon breast. The lower portion is a projected section through C—D.

BUGGY BREASTS.

For inclinations from 10° to 18°, that is, after mule haulage becomes impossible in the breast and before the inclination is such that coal will slide on sheet iron, buggies are used, as shown in fig. 9. These are small cars, into which the coal is loaded at the face, and they are



SECTION OF THE SOUTHERN ANTHRACITE COAL BASIN AT POTTSVILLE.

then pushed by hand along the track, which is built up so that it is nearly level, to the foot of the breast, where the coal is dumped upon a platform, whence it is shoveled into the mine car. In some cases the inclination of the tipple at the foot of the breast is such that the buggy can dump directly into the mine car and thus avoid shoveling.

CHUTE BREASTS.

When the pitch is between 18° and 30°, sheet-iron chutes are placed on the bottom of the breast, and the coal slides down these chutes

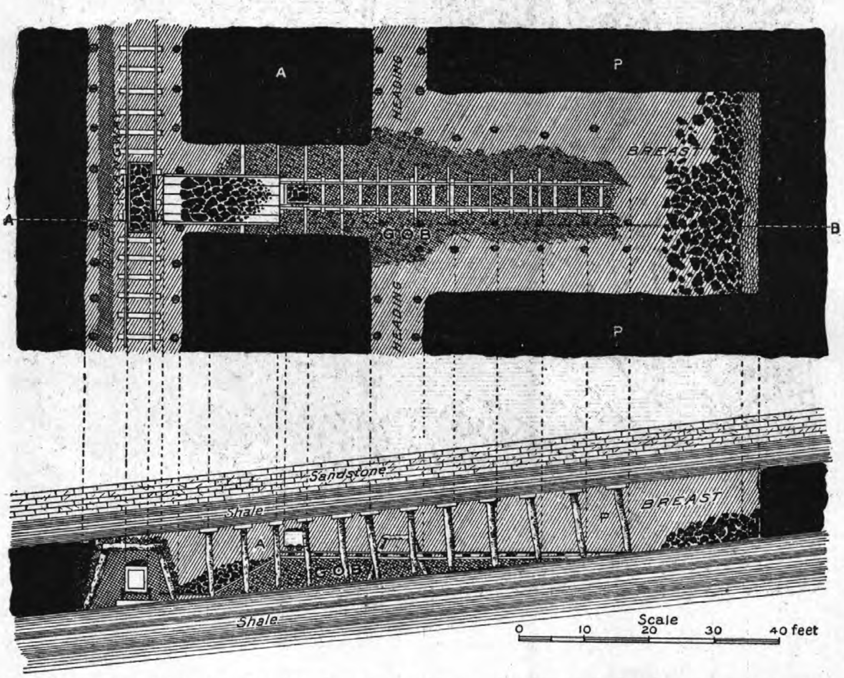


FIG. 9.—Single-chute breast, flat workings, with buggy. The lower portion is a projected section through A—B.

from the face to the bottom, where it passes directly into a car, or else is stopped by a battery of logs built to hold the coal in check so that it can be turned out into the cars as required. (Fig. 10.)

BATTERY WORKINGS.

When the inclination is greater than 30°, coal will slide on the bottom without the use of sheet iron, and it then becomes necessary to stop up the lower end of the breast with a battery built of logs or heavy planks. This acts as a support for the broken coal and allows the breast to fill up with this coal nearly to the face, so that the miners stand upon this broken coal in mining out the face. Only enough coal is drawn off from time to time to keep this working floor at a sufficient distance from the face. (Figs. 11, 12, 13.)

Battery workings may be divided into two general classes: First, where the coal is stored in the breast and the rock and refuse taken out through the chute (fig. 12); and, second, where the rock is stored in a breast and the coal taken out through chutes (fig. 13). The first case applies naturally where there is but little refuse in the coal seam, and the second where a large amount of rock has to be handled in order to mine out the coal. Where rock is allowed to accumulate in the breast a temporary staging is built near the face. Upon this the miners work, and here they separate the rock, which is thrown into

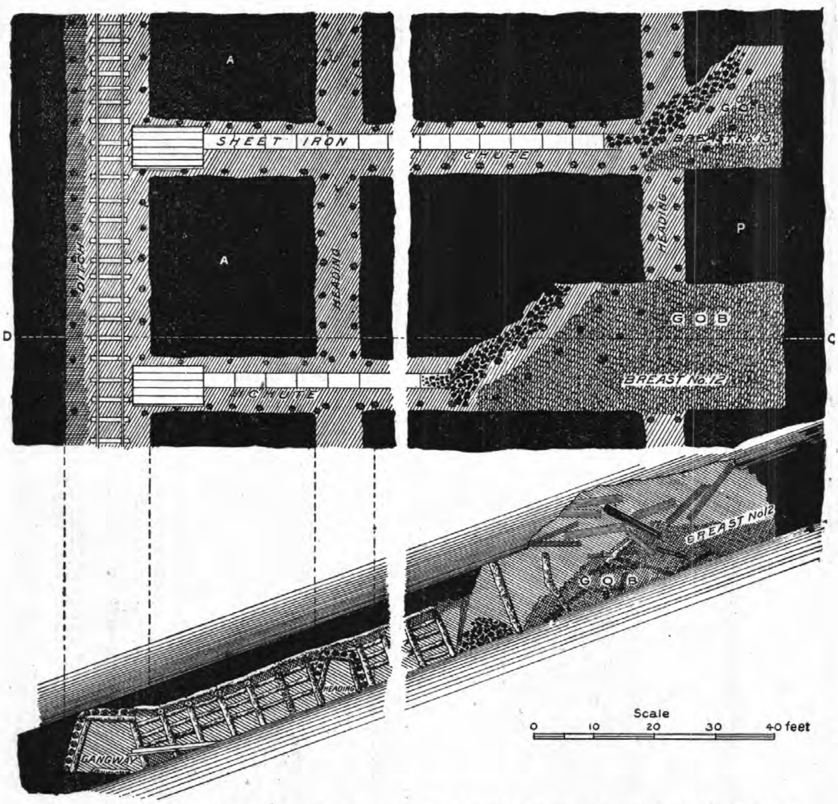


FIG. 10.—Moderate breast, sheet-iron chute. The lower portion is a section through C—D.

the breast, from the coal, which goes through the chutes to the gangway. There is a great variety of arrangement of batteries and chutes, and the figures given show a few of the typical ones, which illustrate sufficiently the general method of battery workings.

WORKING SPLITTINGS OR CONTIGUOUS SEAMS.

When two splits are near together, or when two seams are contiguous, all hauling of the coal is frequently done in the lower seam, the coal from the upper seam or split being conveyed to the lower through chutes or openings put through the intervening rock (fig. 14), or else it may be hauled along horizontal tunnels driven between the seams (fig. 15).

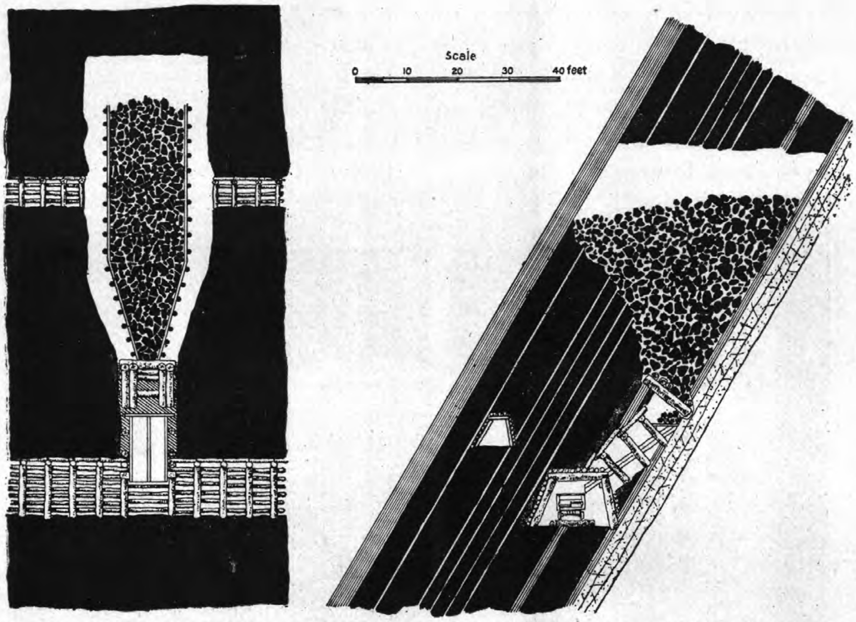


FIG. 11.—Method of working breasts on the Mammoth bed at Hazleton, No. 6 colliery of A. Pardee & Sons.

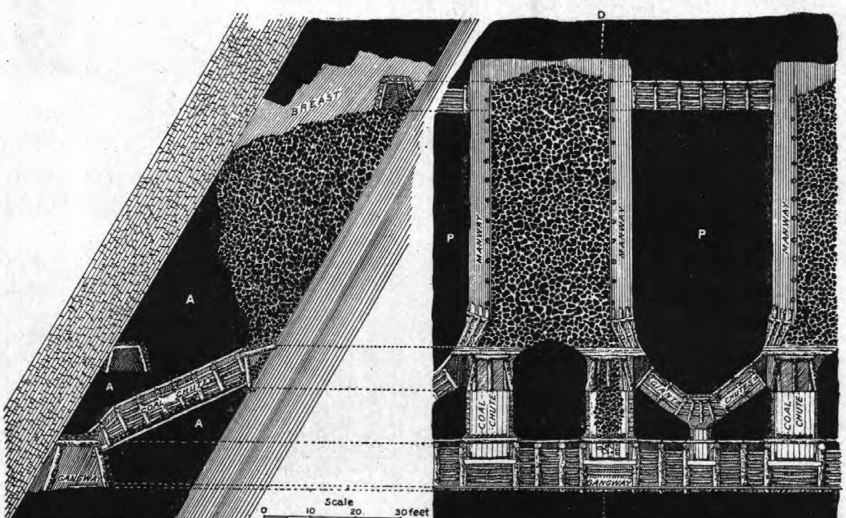


FIG. 12.—Double-chute breasts, with batteries; steep dip.

THICK SEAMS.

Flat, thick seams are worked in one of two ways: First, by driving the full width of the breast in the lower bench from 5 to 8 or 10 feet thick, and then taking down the top coal, retreating from the face backward to the gangway. Second, by opening out the breast to its full thickness and thus driving it to the limit of the lift, the miners reaching the top benches by standing on broken coal or on rude staging.

DRILLING AND BLASTING.

Anthracite is universally mined with hand rotary drills and by the use of black blasting powder. Dynamite or giant powder is used for

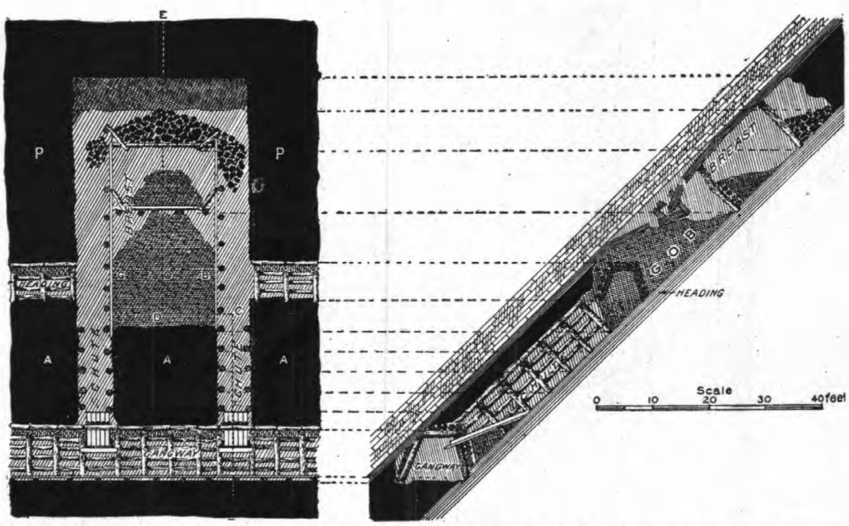


FIG. 13.—Double-chute breast, thin seam, steep pitch. At the right of the figure is a projected section through B—C—D—E.

rock work, sometimes for driving gangways, and in some locations where fire damp necessitates a flameless explosive, but as its effect is to shatter the coal it is not generally used. The flameless explosives of Great Britain and Europe have not been adopted in the

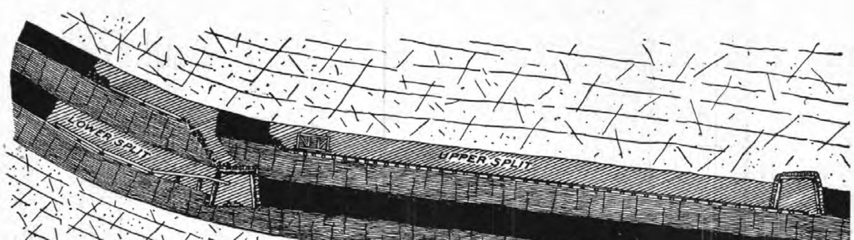


FIG. 14.—Method of working two splits of the Baltimore bed at the Mineral Springs colliery, near Wilkesbarre.

anthracite field. The amount of powder to a ton of coal mined varies greatly under different conditions, and the amount will probably increase with increasing depth and hardness of the coal. The report of the Bureau of Mines of Pennsylvania for 1899 gives, in the table reproduced below, the amounts in use in the several inspection districts, and while average values taken from these would be misleading, the totals are useful as showing one reason why the cost of mining anthracite is so much greater than the cost of mining bituminous coal.

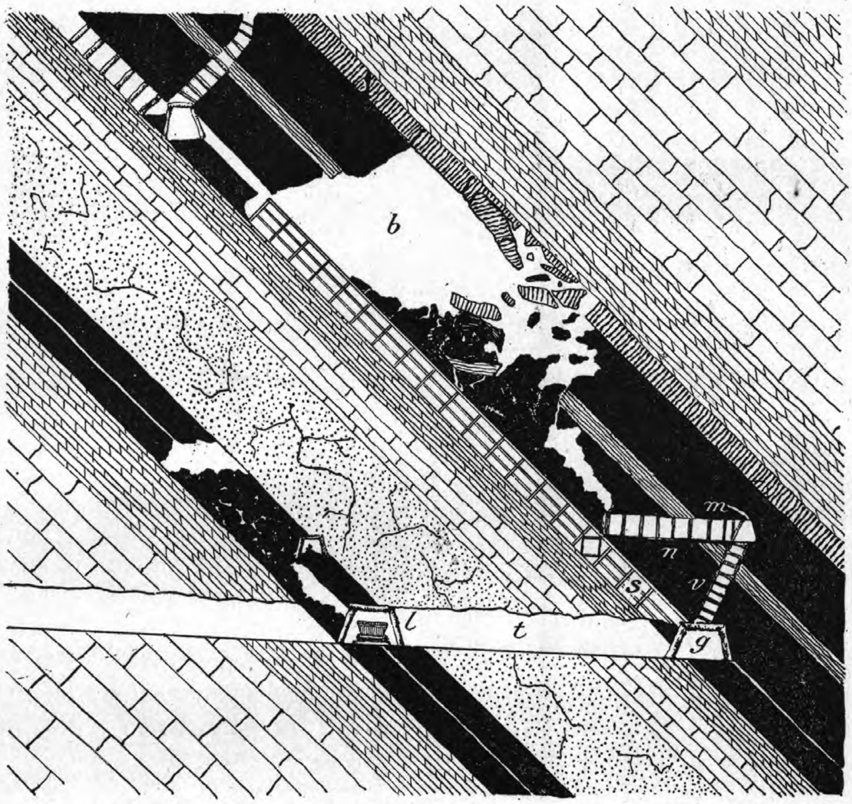


FIG. 15.—Method of working contiguous seams through horizontal rock tunnel.

Table showing amount of powder used in mining anthracite.

Inspection district.	Total production.	Kegs of powder.	Tons of coal per keg of powder.	Pounds of dynamite.
First	7,374,571	244,866	30	121,080
Second	6,774,458	237,891	28.5	113,829
Third	6,854,711	210,320	32	266,688
Fourth	8,648,152	215,209	40	392,868
Fifth	6,191,027	107,172	56.8	1,206,368
Sixth	7,538,404	154,169	48.8	450,914
Seventh	6,308,334	139,724	46	541,429
Eighth	4,344,567	63,340	68.7	556,241
Total	54,034,224	1,372,691	39.3	3,649,417

For the same year, in mining 73,066,943 tons of bituminous coal the average was 282 tons of coal mined per keg of powder, or eight times as much as the average at the anthracite mines during the same period.

The coal is not undercut as a general rule, and mining machines have never been applied successfully to the anthracite field.

VENTILATION AND GAS.

The mines are universally ventilated by rotary fans, which are generally of the Guibal type, although often greatly modified. Closed fans are in general use, though there are a number of instances where open fans are still used.

Fire damp is found in many of the deeper mines, particularly in those of the Wyoming region and in the western end of the Schuylkill region. In a number of mines it exists in such quantities as to render it necessary to work them entirely by the use of safety lamps. The law requires a minimum of 200 cubic feet of air per minute for each and every person employed in a mine, and requires that the velocity of the air current shall not exceed 450 lineal feet in any air passage where gauze safety lamps are used, excepting in the mine inlets and outlets.

HAULAGE.

Every known form of haulage is to be found in the anthracite mines—mule haulage, rope haulage (both endless and tail rope), and locomotive haulage, the locomotives being run by steam, air, or electricity. The cars are usually gathered from the rooms by mules, excepting where the grade of the track is sufficient for them to be run out by gravity. In some instances small compressed-air locomotives have been used for gathering from the rooms with great success and economy, as they do away with brushing down the top to provide head room for mule haulage. Although the first electric locomotive used for mine service in America was installed at Lykens in 1887, the presence of fire damp in some of the mines has deterred many from introducing this form of haulage, although in mines where there is no danger from the presence of fire damp many plants have been installed and are working with great success. The following table, compiled from the report of the chief of the bureau of mines for Pennsylvania for 1899, shows the number of mules and the various forms of motors in use at the anthracite collieries at the close of 1900.

Table showing the variation in the number of mules and different forms of motor haulage at the anthracite mines of Pennsylvania from 1897 to 1900.

	Mules.	Steam locos.	Electric locos.	Compressed-air locos.	Electric dynamos.	Air compressors.
1897	15,877	([a])	([a])	([a])	([a])	([a])
1898	15,907	([a])	11	7	30	([a])
1899	15,690	352	29	24	45	116
1900	15,708	365	38	30	60	139

[a] No report.

The coal is brought to the level of the bottom of the shaft from the higher levels by means of self-acting planes. From lower levels it is hoisted by slopes, which are operated by hoisting engines placed either inside the mine, to which steam, electricity, or compressed air is conveyed from the surface, or else hoisting ropes are run through bore-holes to the surface and there connected with hoisting engines.

The mine cars in use vary in size from those having a capacity of 70 cubic feet to a capacity of 140 cubic feet, or from $1\frac{3}{4}$ tons to 4 tons, the variation in size and the form of the car depending upon the thickness and inclination of the seam. The cars are usually built of wood, with iron bracing, although in some instances steel cars have been used.

FLUSHING OF CULM.

Within recent years the waste culm produced in the preparation of coal has been mixed with water and conveyed through bore-holes back into the workings, where it is used to fill up the portions which have been mined out and where it acts as a support while the pillars are being removed. This not only prevents the disfigurement of the surface with unsightly culm banks, but greatly assists in the removal of coal pillars. Detailed descriptions of this flushing of culm will be found in the following papers:

Flushing culm, by James B. Davis: Association Letter of the Anthracite Coal Operators' Association, February, 1898; and Mines and Minerals, Vol. XVIII, pp. 342–389.

Pillar drawing, by James B. Davis: Mines and Minerals, Vol. XX, p. 289.

Flushing culm, by William Griffith: Journal of the Franklin Institute, April, 1900; and Mines and Minerals, Vol. XX, p. 388.

Flushing culm: Coal and Metal Miner's Pocket Book, p. 314.

PREPARATION OF ANTHRACITE COAL FOR MARKET.

Run-of-mine anthracite consists of lumps of coal of various sizes mixed with more or less rock and bony coal. Unlike bituminous coal, however, it can not be marketed just as it comes from the mines, or after a very simple screening. Anthracite must be broken, sorted to sizes, and have all impurities picked out. Since economical combustion of anthracite requires the pieces to be of as nearly as possible a uniform size, and as there is greatest demand for the intermediate sizes of anthracite, the larger lumps as they come from the mines must be broken down to these smaller sizes. This elaborate preparation greatly increases the cost of coal to the consumer, both on account of the actual cost of the preparation and from the fact that there is considerable necessary loss incident to the breaking up of the coal, since the fine coal will not command as high a price as the intermediate sizes.

Anthracite is prepared for market in a coal breaker, which is a large building built usually of timber, but sometimes of iron or steel.

The coal is broken by toothed rolls and screened in circular revolving screens or in shaking horizontal screens. The slate is picked out by hand by boys or old men, who sit along the chutes through which the screened coal passes, by automatic slate pickers, and, particularly with the smaller sizes, the coal and slate are separated by jigging.

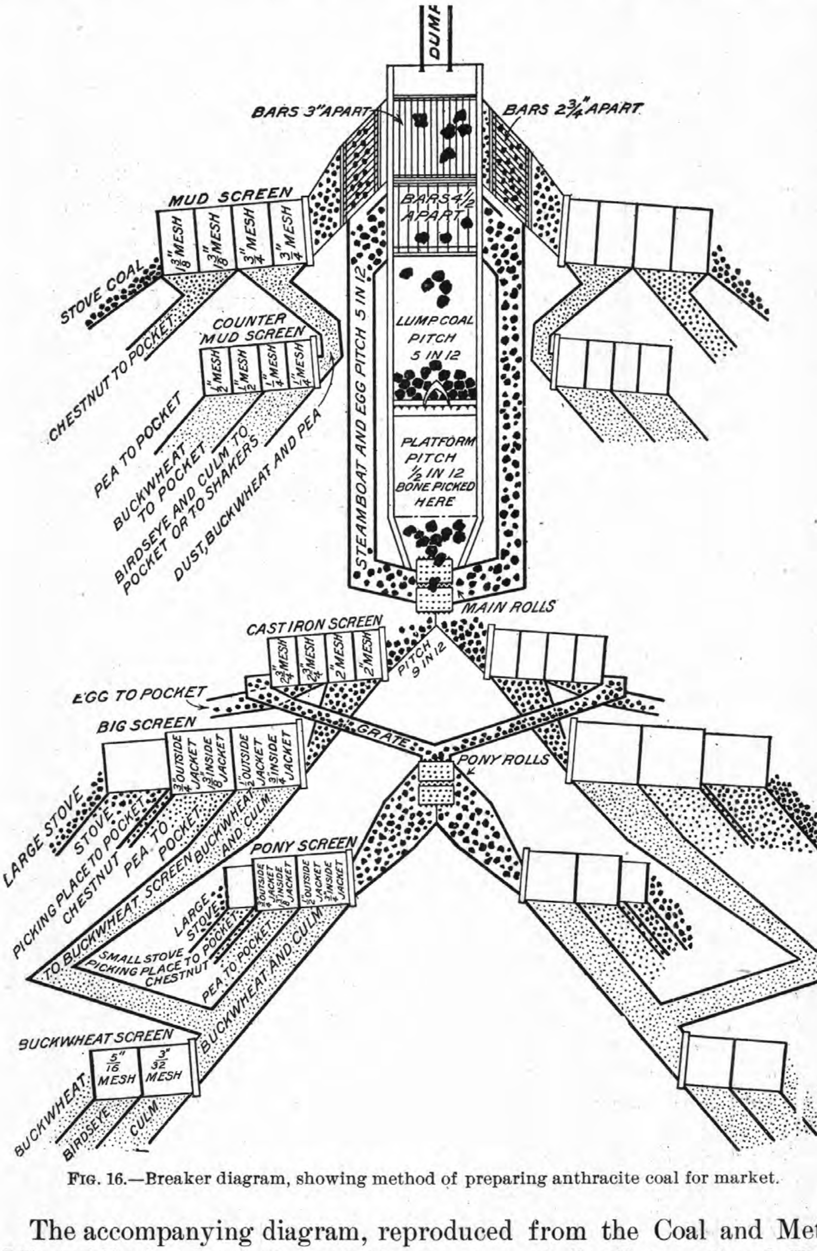


FIG. 16.—Breaker diagram, showing method of preparing anthracite coal for market.

The accompanying diagram, reproduced from the Coal and Metal Miners' Pocket Book through the courtesy of the International Text Book Company, of Scranton, Pa., shows very clearly the general methods used in the preparation of anthracite. The exact arrangement of bars, screens, chutes, and rolls here given does not apply to any particular breaker, but is a generalized type, since no two breakers are probably identical in their detailed arrangement. As the diagram shows, the general plan is to first sort the coal over inclined bars, then to pass what goes through the bars over revolving or over shaking screens, while what goes through goes either directly to the loading bins or else is broken up into smaller sizes by rolls and then separated by screens into the desired sizes. As the demand for various sizes differs at different seasons of the year, the breakers are so arranged that within certain limits any desired amount of any particular sizes can be made at any time. The coal which goes through the bars, instead of being screened, may pass through rolls and be broken up in case there is no demand for the larger sizes.

Coal breakers, as shown by the diagram, are usually divided into two parts, which are duplicates in equipment and so arranged that either one can be run independently of the other. Hence, the breaker can be run to its full capacity or to only one-half capacity. This allows also for the increased work required of a breaker as the output of a mine increases, and possibly for several years after a breaker is first started, if the mine is a new one, only one-half of it will be used until the mine is entirely developed.

The capacity of the breakers now building is from 2,000 to 3,000 tons of prepared coal a day, and the cost of building and equipping such a structure is approximately $100,000. Some of the recent mammoth breakers contain over a million feet of lumber.

The following table gives the ordinary sizes of anthracite, and the mesh of screen used in preparing these sizes.

These sizes are not fixed with any great uniformity, but the screen perforations given are probably as nearly an average as can be obtained.

SIZING OF COAL.

Lump over bars placed 7 to 9 inches apart.

Steamboat over bars placed $3\frac{1}{2}$ to 5 inches apart and through bars placed 7 to 9 inches.

Broken or grate passes over $2\frac{3}{4}$-inch mesh and out of end screen.

Egg passes over 2-inch mesh and through $2\frac{3}{4}$-inch mesh.

Stove passes over $1\frac{3}{8}$-inch mesh and through 2-inch mesh.

Chestnut passes over three-fourths-inch mesh and through $1\frac{3}{8}$-inch mesh.

Pea passes over one-half-inch mesh and through three-fourths-inch mesh.

Buckwheat No. 1 passes over one-fourth-inch mesh and through one-half-inch mesh.

Buckwheat No. 2 passes over one-eighth-inch mesh and through one-fourth-inch mesh.

Buckwheat No. 3 passes over three-thirty-seconds-inch mesh and through one-eighth-inch mesh.

Birdseye passes over one-fourth-inch mesh and through five-sixteenths-inch mesh.

Rice passes through three-sixteenths-inch mesh (round) and one-eighth inch (square).

Culm passes through three-thirty-seconds-inch mesh.

The following tables show the variation in the percentages of the various sizes as made at different periods of the year:

Percentages of different sizes.

LEHIGH REGION.

Month.	Lump.	Steamer.	Broken.	Egg.	Stove.	Chestnut.	Pea.
1895.							
January	10.56	....	23.59	18.27	18.69	14.21	14.68
February	12.34	....	22.54	18.11	17.98	14.50	14.53
March	11.85	....	19.26	18.81	19.69	13.18	17.21
April	12.81	....	19.21	18.35	19.48	11.14	19.01
May	13.81	....	19.11	18.35	19.01	11.32	18.40
June	15.29	....	18.60	17.73	19.08	11.23	18.07
July	14.26	....	19.89	17.41	18.30	11.25	18.89
August	13.56	....	20.26	18.10	17.72	11.49	18.87
September	12.31	....	20.41	18.27	18.28	11.61	19.12
October	12.21	....	18.01	19.15	18.89	12.28	19.46
November	11.40	....	18.53	19.78	19.79	12.01	18.49
December	10.78	....	19.56	20.09	20.32	12.07	17.18
Year	12.58	....	19.71	18.59	18.99	12.15	17.98

WYOMING REGION.

Month.	Lump.	Steamer.	Broken.	Egg.	Stove.	Chestnut.	Pea.
1895.							
January	8.21	0.02	17.53	20.31	21.46	18.04	14.43
February	8.29	.12	17.75	20.41	20.85	17.44	15.14
March	6.20	.55	17.64	20.04	20.65	18.00	16.92
April	7.01	.38	16.76	20.17	20.92	18.12	16.64
May	4.79	.27	18.63	20.33	21.42	18.23	16.33
June	3.29	.21	22.43	19.72	20.21	18.57	15.57
July	7.84	.42	19.42	19.54	19.46	18.58	14.74
August	5.05	.57	19.84	20.69	18.92	18.62	16.31
September	4.25	.27	18.81	21.98	19.98	19.32	15.39
October	4.72	.01	16.77	22.00	21.27	19.88	15.35
November	2.69	.16	15.56	22.42	22.66	20.71	15.80
December	4.40	.57	14.03	22.62	21.27	21.41	15.70
Year	5.23	.29	17.96	20.95	20.80	19.03	15.74

It is possible to make any quantity of any given size of coal, but any variation from the ordinary stock sizes means greatly increased expense to the consumer.

A great change has taken place in recent years in the relative amounts of the different sizes used. The production of the larger sizes, above grate, has been largely discontinued, while the amount of pea and smaller sizes has greatly increased. The proportion of small coal to the total output has increased enormously.

The rapid increase in the production of the small sizes as compared with chestnut and the larger sizes is well shown by the diagram form-

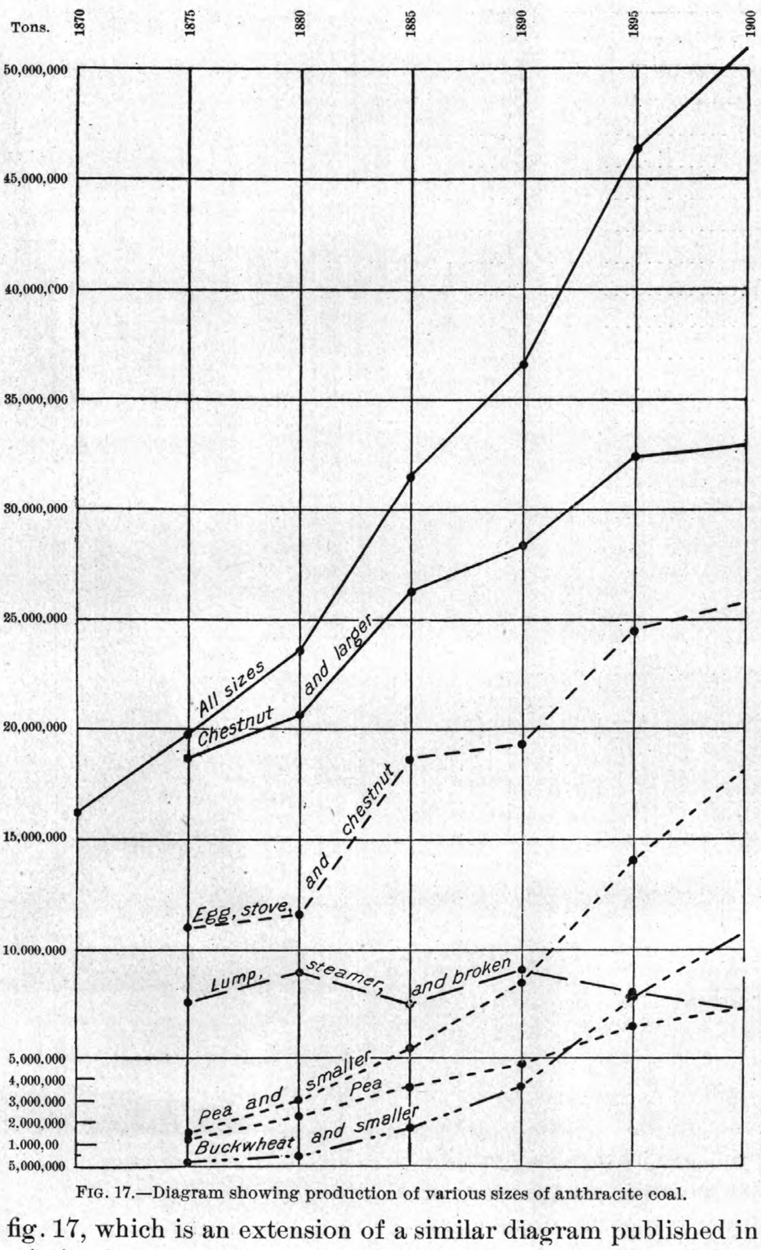


FIG. 17.—Diagram showing production of various sizes of anthracite coal.

ing fig. 17, which is an extension of a similar diagram published in the Association Letter of the Anthracite Coal Operators' Association for April, 1899.

The reason for this decline in the use of the larger sizes, steamer and broken, is the higher prices of these sizes compared with the price of bituminous coal and with those of the smaller sizes, the use of which is increasing. In breaking down the larger sizes, there is an increased amount of the smaller sizes made, thus increasing the average cost of all sizes to the producer.

The average production of each size in percentages is about as follows, based upon the figures for the year 1898:

Increase in use of various sizes.

	1898.
	Per cent.
Lump	4.31
Steamer	1.07
Broken	9.48
Egg	14.17
Stove	21.82
Chestnut	19.10
Total of large sizes	69.95
Pea	13.83
Buckwheat	13.40
Buckwheat No. 2	1.10
Rice	1.38
Culm	.34
Total small sizes	30.05

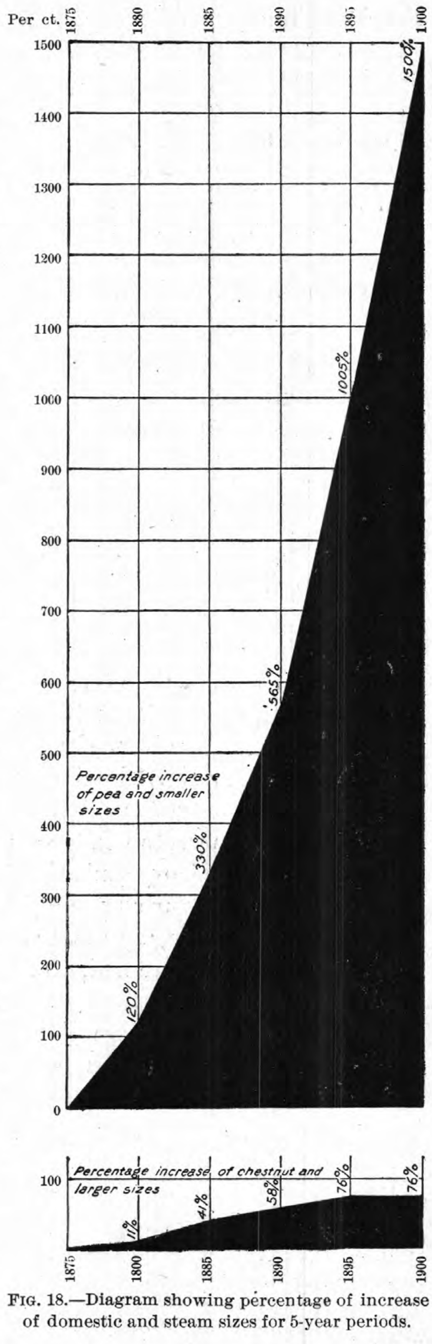


FIG. 18.—Diagram showing percentage of increase of domestic and steam sizes for 5-year periods.

The Anthracite Coal Operators' Association estimates that the production of buckwheat and smaller sizes available for shipment will not average over 12 per cent of the entire output, when the production per month is 2,500,000 tons or less, but that it will average 17 to 18 per cent when the monthly output is 4,500,000 tons. Hence 300,000 tons would be available one month and 800,000 tons another month, thus showing the extreme uncertainty of the available supply.

As these smaller sizes are used mainly for steam purposes, they come into direct competition with bituminous coal. The following facts from the Anthracite Coal Operators' Association Letter in regard to these small sizes are therefore of interest and importance:

"Small sizes of anthracite—buckwheat Nos. 1 and 2 and culm—contain 75 to 85 per cent carbon. The advantages of this fuel are that it is not subject to spontaneous combustion under ordinary conditions; it is a smokeless fuel, and can be purchased at a very low cost at the mines. This makes it a formidable competitor with bituminous coal wherever it is not discriminated against by excessive freight rates and in locations where a regular supply is available.

"Although culm costs only 25 cents to 50 cents per ton at the bank, the cost for transporting it any distance takes it out of competition with bituminous coal excepting in close proximity to the mines.

"Another item which works against the more general use of the smaller sizes of anthracite is the ignorance of many firemen as to the proper method of firing with the small sizes, or a failure upon the part of manufacturers to adopt modern and practical methods of burning them.

"It has been demonstrated in practice that in most cases the small sizes of anthracite can be burned to best advantage by a forced blast under the grate, the blast being furnished by a fan or steam jet. Small sizes should be burned with as thin a bed as is consistent with steady firing—for No. 1 buckwheat, say 5 to 7 inches; for No. 2 buckwheat, 5 to 6 inches; for culm, 4 to 5 inches. A large grate area is also essential, the grate being as nearly a plane surface as possible. The grate should also permit the fire to be cleaned without keeping the fire doors open for any length of time. It should also be a clinker-shearing grate, having graduated fire spaces for regulating the drafts and for shaking the fire bed, to reduce its thickness, and to create new air courses.

"So much depends upon the form of furnace and grate used and upon the skill of the fireman that it is impossible to give any very definite comparative values for the smaller sizes of anthracite and for bituminous coal, particularly since there is so wide a variation between the different varities of each of these fuels.

"Until more conclusive tests have been made, we shall have to make use of the generally accepted figure which assumes a difference of 10 per cent in favor of bituminous coal when calculating its steaming value as compared with the small sizes of anthracite.

"The following analyses, which may be considered, roughly speaking, as standard and averages for the two fuels, will give a rough approximate basis for comparison."

Comparative analyses of anthracite and bituminous coal.

	Anthracite.	Bituminous.
Fixed carbon	87.48	70.50
Volatile matter	7.51	24.20
Ash	5.01	5.30

In a paper read before the Individual Operators Association on January 9, 1895, Mr. William McClave made the following comparison between the various sizes of coal:

Relative value of various classes of bituminous and anthracite coal, based on 100 as standard.

Bituminous coal, good quality	100
Bituminous slack, good quality	90
Anthracite steamboat, good quality	95
Anthracite broken, good quality	97
Anthracite egg, good quality	100
Anthracite stove, good quality	100
Anthracite chestnut, good quality	100
Anthracite pea:	
Well cleaned and of good quality	95
Mixed with bone and slate	90
Anthracite buckwheat No. 1, good quality	93
Anthracite buckwheat No. 2, good quality	85
Anthracite buckwheat No. 3, good quality	83
Anthracite culm No. 1 (anthracite dust with Nos. 1, 2, and 3 buckwheat), mixed with 20 per cent soft coal slack, good quality	83
Anthracite culm No. 2 (anthracite dust with Nos. 2 and 3 buckwheat), mixed with 20 per cent soft coal slack, good quality	77
Anthracite culm No. 1 (alone), good quality	75
Anthracite culm No. 2 (alone), good quality	70

"In actual practice it is stated that from 8 to 14 per cent more of the anthracite small sizes are required than when using good quality bituminous coal. The Pennsylvania Railroad has found that its locomotives required 10 to 14 per cent more anthracite than soft coal, and on another railroad about 10 per cent more was required.

"Assuming a freight rate to New York City of only $1.10 to $1.20 on the small sizes, 12 cents for royalty and 3 cents for repairs to cars to prevent loss in transmission, which loss would fall upon the shipper, we find the actual cost in New York to be about $1.35, to which must be added the cost of mining and preparation. If we assume this to be only $1.25, a figure which is seldom reached, the cost of the fine coal in New York will be $2.60. This shows conclusively its disadvantage when it comes into competition with bituminous coal, which frequently sells for less than $2."

STORAGE DEPOTS.

The demand for anthracite varies greatly with the season of the year, and during the summer months there is comparatively no demand for the domestic sizes, which, as has been shown, make up the bulk of the product. On the other hand, this is the season when the coal must be shipped to the territory bordering on the Great Lakes while water navigation is possible. For these two reasons storage plants have been erected by the transportation companies, where large stocks of coal are kept on hand.

The following table gives the calculated average percentages for the production per month, extending over a period of five years, and also the actual percentages for the year 1899 by way of comparison:

Calculated average percentage of production per month.

Month.	Calculated average for five years.	Actual shipments in 1899.
	Per cent.	*Per cent.*
January	7.22	7.8
February	6.02	6.8
March	6.54	7.1
April	6.40	6.4
May	7.46	7.4
June	8.50	8.5
July	8.94	8.7
August	8.72	9
September	9.16	9.1
October	11.14	10
November	10.90	9.8
December	8.62	9.4
First six months	42.14	44
Second six months	57.86	56

The cost of mining anthracite can not be given in general terms, as it varies so greatly in different sections and under different conditions. In the Individual Operators' Letter for April, 1899, Mr. Fleming assumes $1.60 per ton, and in the same publication for November, 1898, Mr. John C. Haddock assumes $1.50 per ton as the cost of mining. The Coal and Metal Miners' Pocket Book gives the mean cost at a number of collieries in the Wyoming field as $1.359 for the year 1895, exclusive of royalties and taxes. In this same Pocket Book the cost at several collieries in the Lehigh region during the same year was $1.546, exclusive of royalties and taxes.

CHARACTER OF LABOR EMPLOYED IN ANTHRACITE MINING.

Some years ago the anthracite miners were mainly American, English, Welsh, and Irish; but at present a great many nationalities are represented on the pay rolls of the anthracite field. We have no data for the relative numbers of the different nationalities among those employed excepting the percentages given by the mine inspectors for those injured, but as the different nationalities are found in all grades of mine work these percentages will probably give a close approximation to the actual percentages among the several classes of workmen.

Numbers and percentage injured of different nationalities, by inspection districts.

Nationality.	First.	Second.	Third.	Fourth.	Fifth.	Sixth.	Seventh.	Eighth.	Total.	Percentage.
American	29	34	65	59	22	12	36	60	317	21.19
Irish	32	55	46	27	17	28	26	12	243	16.24
English	21	14	11	8	6	6	7	4	77	5.15
Welsh	21	33	11	52	2	5	5	6	135	9.02
Polish	40	32	72	81	18	112	37	19	411	27.47
Hungarian	12	1	23	....	35	1	10	10	92	6.15
Russian	2	2	5	....	....	....	....	....	9	.60
Austrian	7	4	....	5	8	....	1	....	25	1.67
Slavonic	5	1	7	14	....	....	....	1	28	1.87
Greek	1	....	....	....	....	....	....	....	1	.06
Italian	8	9	10	1	15	2	....	....	45	3.06
Scotch	3	3	3	....	1	....	6	....	16	1.06
German	2	11	17	8	5	4	12	5	64	4.27
French	1	1	....	....	....	....	2	1	5	.33
Swedish	....	4	1	4	....	....	....	....	9	.60
Bohemian	....	1	....	....	....	....	....	....	1	.06
Lithuanian	....	3	....	12	....	....	....	1	16	1.06
Tyrolian	....	....	....	....	....	1	....	....	1	.06
Spanish	....	....	....	....	....	....	....	1	1	.06
Total	184	208	271	271	129	171	142	120	1,496	99.98

The number of employees in each class of labor is shown by the following table, taken from the report of the chief of the bureau of mines, of Pennsylvania, for 1899:

Number of employees in each class of labor, according to inspection districts.

Employment.	First.	Second.	Third.	Fourth.	Fifth.	Sixth.	Seventh.	Eighth.	Total.
Inside foremen of mine bosses	56	51	72	57	57	48	69	44	454
Fire bosses	54	82	107	159	51	135	241	101	930
Miners	4,992	4,066	4,543	5,466	3,147	4,751	6,301	3,165	36,431
Mine laborers	4,160	3,595	3,401	4,980	1,733	2,613	2,051	1,413	23,946
Drivers and runners	1,739	1,585	1,672	2,010	698	862	1,042	520	10,128
Door boys and helpers	339	421	432	897	212	269	345	176	3,091
All other employees	1,295	1,173	1,424	2,539	1,647	3,491	3,234	2,319	17,122
Total inside	12,635	10,973	11,651	16,108	7,666	12,169	13,283	7,738	92,223
Outside foremen	42	41	45	44	45	42	44	40	343
Blacksmiths and carpenters	198	185	225	284	339	305	304	239	2,079
Engineers and firemen	408	335	495	664	635	749	638	520	4,444
Slate pickers	2,015	2,273	2,370	3,901	2,262	3,506	2,956	1,811	21,094
Superintendents, bookkeepers, and clerks	84	79	109	113	104	114	99	76	778
All other employees	1,761	1,533	2,261	2,554	3,242	3,020	3,066	2,258	19,695
Total outside	4,508	4,446	5,505	7,560	6,627	7,736	7,107	4,944	48,433
Total inside and outside	17,143	15,419	17,156	23,668	14,293	19,905	20,317	12,682	140,583

STATISTICS OF MINES AND PRODUCTION.

The production of coal in the anthracite field, by decennial periods since 1880, is shown in the accompanying table, and the production for each year of the same period is shown graphically on the diagram forming fig. 19:

Development of the Pennsylvania anthracite coal field, by decennial periods.

1880:		
Production	tons	28,711,379
Value		$42,282,948
Average price per ton		1.47
1890:		
Production	tons	46,468,641
Value		$66,383,772
Average price per ton		1.43
Increase of 1890 over 1880:		
Product	tons	17,757,262
Per cent		62
Value		$24,100,824
Per cent		57
1900:		
Production	tons	57,367,915
Value		$85,757,851
Average price per ton		1.49

Increase of 1900 over 1890:

Product	tons	39, 610, 653
Per cent		22. 3
Value		$18, 374, 079
Per cent		28

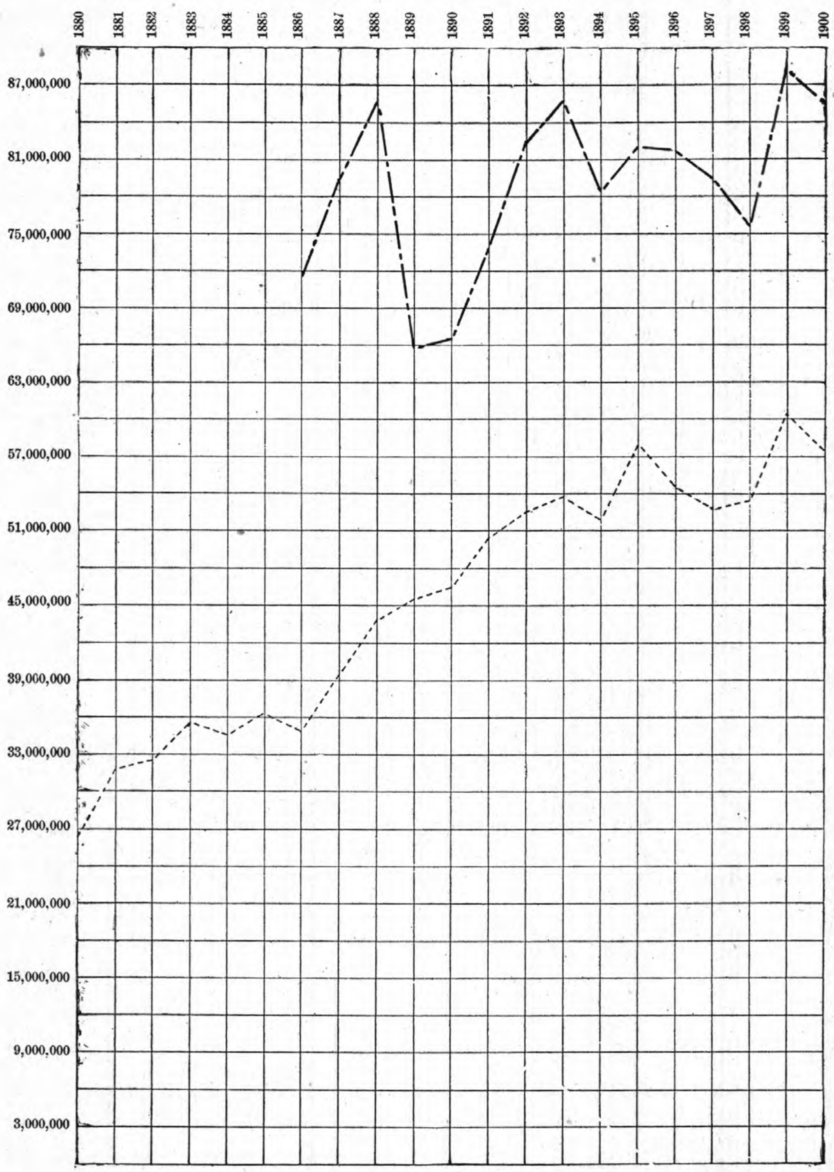


FIG. 19.—Diagram showing production and value each year from 1880 to 1900.

. . . . Production.
—— – ——— – —— Total value.

Scale {3,000,000 tons to the square. / $3,000,000 to the square.}

FUTURE DEVELOPMENT.

Concentration of interests has been the policy for the last few years in connection with the mining and preparation of the coal, as well as in the ownership of the properties. Large central plants are rapidly replacing isolated smaller plants. One large breaker now does the work formerly done by a number of small ones. A single tubular boiler plant has replaced possibly half a dozen scattered individual plants of old-fashioned cylindrical boilers, and mammoth central pumping plants or drainage tunnels are now draining whole basins, where formerly a large number of small plants were doing the work. This concentration naturally tends to better management, and to a saving in fixed expenses and in labor.

These economies have been made necessary from the fact that there has been a steady increase in the capital and labor required to produce anthracite, while there has not been a corresponding increase in the demand for it. In 1880 coal royalties were from 20 to 25 cents per ton for prepared sizes, no account being taken in many cases of sizes below chestnut, and upon some of the old culm banks a large amount of chestnut even was thrown. Royalties are now from 40 to 50 cents, and in occasional instances even higher, for prepared sizes above pea, 25 cents for pea coal, and about 10 to 12½ cents for small sizes below pea. In 1877 the average number of days worked in a year was 205. In 1897 it was only 152. The cost of opening a colliery in 1887 was $100,000; now it is from $400,000 to $500,000. Moreover, the coal did not then have to be so clean or so exactly sized as now, from 12 to 15 per cent of bone being allowed in chestnut and 8 to 10 per cent in stove, as against 6 per cent and 3 per cent, respectively, now. Hence at present about 14 per cent of the product which was formerly salable must be thrown upon the dump. In 1887 the average daily breaker output was 500 tons, with a maximum of 1,800 to 2,000 tons, while in 1897 the average of all breakers was 880 tons a day and the maximum 2,600 tons and over, which maximum has been increased to 3,000 tons in 1900, while the complete cost of equipment of a colliery in the latter year was probably $700,000. In 1880, 88 per cent of the coal sold was of the size which was sold at a profit, while in 1897 only 70 per cent of the total sales were of profitable selling sizes. In 1877, 38 per cent of all coal mined was grate and larger sizes, which required practically no crushing or preparation for sale. By 1887 this amount had decreased to only 26 per cent; in 1897 it was 15 per cent. The selling price of prepared sizes at tide water was $3.26 in 1877, $3.67 in 1887, and $3.46 in 1897.

The coal near the surface and in the thicker seams has in many places been worked out, necessitating deeper workings, heavier machinery, and increased costs in many ways in connection with mining, while the greater purity of the salable product has greatly increased the cost of preparation.

The following table shows the change in output, by years, comparison being made in each case with the output of the preceding year:

Increase and decrease of anthracite output from 1880-1900.

[Increase, +; decrease, —.]

	Per cent.		Per cent.
1880	—10.3	1891	+10.4
1881	+21.4	1892	+ 3.5
1882	+ 2.2	1893	+ 2.8
1883	+ 9.3	1894	— 3.9
1884	— 3.4	1895	+12.3
1885	+ 2.9	1896	— 7.1
1886	+ 1.6	1897	— 4.5
1887	+ 7.8	1898	+ .4
1888	+10.1	1899	+14.
1889	— 6.9	1900	[a]— 5.2
1890	+ 2.2		

The average decrease as shown by this table was 6 per cent, and the average increase 6.9 per cent. During the eighteen years tabulated, twelve show an increase and six a decrease. The accompanying diagram, fig. 19, shows the production for each year since 1880 and the value since 1886. Other tables showing the rate of decrease in three-year, five-year, and ten-year periods will be found in the "Coal Trade," published by F. E. Saward, New York City, for 1900. These tables show an increase, but in a decreasing ratio. A number of estimates have been made as to when the maximum output will be reached, and while some figure out a gradual and steady increase for a number of years to come, the more conservative and reliable estimates fix the period of maximum production early in the present century.

Anthracite will probably be mined while any of it remains in the ground, or at least for a great many years to come. An industry in which the invested capital amounts to at least $700,000,000 and the value of whose natural profit is from $85,000,000 to $100,000,000, while its freight traffic nets the carriers $40,000,000 per year, can not be wiped out of existence with the rapidity that some pessimists would have us think.

In 1896 Mr. William Griffith wrote as follows:[b]

The present annual capacity of the anthracite region, working three hundred days per year, is about 67,000,000 tons, while the market will take but 46,000,000, or a capacity 21,000,000 tons ahead of annual consumption, a situation of affairs which requires shrewd and careful management to maintain a profitable business. How long this condition can endure depends on the market and the manner in which the industry is handled by those in control. With the present rate of increase of annual consumption it ought not to continue many years, for the Wyoming and Lehigh regions, which together yield about 70 per cent of the annual tonnage, seem to be nearing their maximum output.

The Hazleton district of the Lehigh region has probably already reached this

[a] Due to strikes.

[b] Bond Record, June, 1896, p. 502.

point. A future development in the Schuylkill region ought not to progress faster than is necessary to meet the demands, especially in view of the fact that the lands are so largely controlled by the transportation companies, and lands for individual enterprises are very limited and more expensive to develop than formerly.

Statistics show that from 1887 to 1897, while the number of dwellings in the territory supplied with anthracite increased 24 per cent and the population 19 per cent, the consumption per dwelling decreased 14 per cent, and the consumption per capita 9 per cent, indicating an increase in the use of gas for cooking purposes and of steam heat from central plants for heating purposes.

The per capita consumption between 1870 and 1900 varied as shown in the following table.

The reason for this decrease is the cheapness of bituminous coal, the extension of central steam heating plants in towns and cities, and the increasing use of gas. The increase of apartment houses has also affected it, as these houses havé their own steam-generating plants, which use soft coal or a reduced amount of anthracite, while a large amount of the cooking is done with gas. Mr. Griffith estimates that a town of 5,000 inhabitants can, in most cases, support a central steam heating plant.

The consumption per capita in the States using over 95 per cent of the entire anthracite production is given by the Eleventh Census as follows:

Consumption of anthracite coal in States using 95 per cent of anthracite product.

State.	Population 1889.	Consumption anthracite 1889.	Consumption per capita.
		Tons.	*Tons.*
Pennsylvania	5, 258, 014	[a]16, 156, 795	3. 07
New Jersey	1, 444, 933	3, 959, 195	2. 73
New York	5, 997, 858	10, 985, 498	1. 83
Rhode Island	345, 506	533, 498	1. 54
Massachusetts	2, 238, 943	3, 274, 133	1. 40
District of Columbia	230, 396	481, 088	1. 35
Delaware	168, 493	230, 421	1. 35
Connecticut	746, 258	964, 967	1. 30
Vermont	332, 422	373, 891	1. 12
Maine	661, 086	580, 232	. 90
New Hampshire	376, 530	334, 569	. 88
Maryland	1, 042, 390	622, 883	. 60
Wisconsin	1, 686, 880	940, 502	. 56
Illinois	3, 826, 351	1, 980, 180	. 51
Minnesota	1, 301, 826	477, 009	. 37
Michigan	2, 093, 889	558, 243	. 27
Total	27, 751, 775	42, 453, 104	1. 53

[a] Includes local consumption at mines.

DISTRIBUTION.

LOCATION AND CHARACTER OF MARKETS.

The approximate distribution of the anthracite product is shown by the following table:

Approximate distribution of anthracite coal shipments in 1899.

State.	Tons of 2,240 pounds.	State.	Tons of 2,240 pounds.
Alabama	1,500	Nebraska	149,850
Arkansas	500	New Hampshire	370,810
California	9,368	New Jersey	4,693,500
Connecticut	1,185,882	New York	12,503,896
Delaware	249,405	North and South Dakota	2,000
Georgia	36,662	Ohio	672,370
Illinois	2,188,294	Oklahoma	893
Indiana	198,998	Oregon	4,000
Iowa	237,456	Pennsylvania	13,803,253
Kansas	20,842	Rhode Island	553,495
Kentucky	19,425	South Carolina	41,288
Louisiana	16,000	Tennessee	6,760
Maine	633,490	Texas	12,949
Maryland and District of Columbia	1,252,832	Vermont	405,095
Massachusetts	3,994,859	Virginia	305,700
Michigan	592,094	Washington	2,500
Minnesota	518,163	West Virginia	366
Mississippi	535	Wisconsin	942,599
Missouri	318,316	Exports	1,707,796
Montana	200	Total	47,665,203
North Carolina	11,262		

This table shows clearly that a very large portion of the product is marketed in a territory closely contiguous to the mines—that is, in the Eastern and Middle States—while the only considerable part that goes out of this section goes to the States bordering on the Great Lakes, which can be reached by water transportation. Anthracite is par excellence a domestic fuel, on account of its cleanliness and the permanence and smokeless character of the fire produced with it. In 1831 Dr. Geissenhainer applied for a patent for making pig iron with anthracite, and in 1838 it was used for this purpose at Mauch Chunk and Pottsville blast furnaces. In 1855 anthracite replaced charcoal as the leading blast-furnace fuel, and from that date until 1875 it retained this place, but at the latter date it was superseded by coke, and it has since steadily declined in importance, so that at the present time there are very few blast furnaces using anthracite for fuel. It has also disappeared almost entirely from use for steamboats, and its use at present in the production of steam in manufacturing plants is confined largely to the use of the smaller sizes.

The use of anthracite upon railroads is confined to the anthracite coal carriers, and even here its use is not now so general as was formerly the case, since many of them find it more profitable to use bituminous coal, particularly for freight traffic.

The amount used for manufacturing purposes is practically represented by the amount of the smaller sizes shipped, and the amount used for domestic purposes by the larger sizes, although it must be borne in mind that a large amount of pea coal is at present used for domestic purposes, and statistics are not available to separate the amounts of pea coal used for domestic and for manufacturing purposes.

TRANSPORTATION FACILITIES.

The first shipments of anthracite coal were made by water, and a certain part of the output has been shipped in this way ever since over the following canals:

(1) The Pennsylvania Canal, running from Nanticoke to Sunbury and thence to Port Deposit, Md.; (2) the Delaware and Hudson Canal, extending from Honesdale to Rondout, N. Y., and (3) the Canal of the Lehigh Coal and Navigation Company, extending from Mauch Chunk to Easton, and thence by the Morris Canal to Perth Amboy, or by canal along the Delaware to Philadelphia. The third of these canals is the only one in active operation at the present time. The Delaware and Hudson Canal was abandoned in 1899 and the canal bed sold to the Delaware Valley and Kingston Railroad, which was the projected railroad of the individual operators in opposition to the present transporting companies.

Another feature of historical interest in connection with the transportation of anthracite is the gravity railroads and planes which were formerly so extensively used for transporting coal over the mountains which surround the basins in which it is mined. Two of these are particularly well known, as they have been favorite resorts for tourists for a number of years. First, the Switch Back at Mauch Chunk, which was originally built to transport coal from the Panther Creek district to the canal at Mauch Chunk; for a number of years it has been used simply for transporting tourists. Second, the Gravity Road, extending from Carbondale to Honesdale, and used to transport coal from the upper end of the Lackawanna Valley to the Delaware and Hudson Canal at Honesdale. This was also well known to tourists, but was discontinued when the Delaware and Hudson Canal was given up, and has been replaced by a broad-gage railroad.

These gravity roads consisted of a series of inclined planes up which cars were hauled by stationary engines located at the top of the inclines. From the apex, or point of highest inclination of a plane, the car ran by gravity for a distance until another plane similar to the first was met, and thus by a succession of planes and gradual descents, the summit was reached. The return track was generally laid so that it required fewer planes than the loaded track to take the empty cars to the place of starting.

Coal is also carried from the valleys to the top of the surrounding mountains by means of a series of inclined planes, but without the intervening stretches over which the trains were run by gravity. Examples of this are the Ashley planes of the Central Railroad of New Jersey, and the Mahanoy plane of the Philadelphia and Reading Coal Company, the latter of these two having been abandoned only recently.

The facilities for transporting anthracite from the mines to tide water, to the Great Lakes, and to the contiguous thickly populated sections of the country, where the bulk of it is consumed, are ample, as eleven railroads traverse or emanate from the region. These roads, which are shown on the accompanying map, Pl. VI, are given in the following table, and their relative importance as coal carriers is indicated by the percentages of the total output of anthracite carried by each.

Anthracite coal-carrying companies.

Name of railroad.	Name of affiliated coal company.	Headquarters of mining operation.	General superintendent of mine operations.	Shipments in 1900.	Allotment—percentage according to agreement made January, 1896.
				Tons.	
Delaware, Lackawanna and Western.	Coal department Delaware, Lackawanna and Western Railroad.	Scranton	E. E. Loomis	6,013,849	13.35
Delaware and Hudson Canal Co.	Coal department Delaware and Hudson Canal Company.	....do	C. C. Rose	3,973,859	9.60
Erie and Wyoming Valley Railroad.	Pennsylvania Coal Company		W. A. May	2,090,153	4.00
Erie Railroad	Hillside Coal and Iron Company.	Dunmore	....do	1,741,069	4.00
New York, Susquehanna and Western.	Absorbed by Erie			1,333,848	3.20
New York, Ontario and Western.	Scranton Coal Company; New York and Scranton Coal Company.	Scranton	J. R. Bryden	1,658,457	3.10
Pennsylvania Railroad	Coal companies of the Pennsylvania Railroad.	Wilkesbarre	Morris Williams	5,169,947	11.40
Lehigh Valley Railroad	Lehigh Valley Coal Company	....do	S. D. Warriner	6,909,442	15.65
Delaware, Susquehanna and Schuylkill.	Cross Creek Coal Company	Drifton	I. A. Stearns	1,568,488	3.50
Central Railroad of New Jersey.	Lehigh and Wilkesbarre Coal Company.	Wilkesbarre	W. J. Richards	5,309,856	11.70
Philadelphia and Reading Railroad.	Philadelphia and Reading Coal and Iron Company.	Pottsville	R. C. Luther	9,338,516	20.50

Some of the transportation companies carry only the coal mined by their own mining companies Others transport coal thus mined and also coal mined by individual operators upon the property of the railroad. Still others receive coal from both of these sources, and also from individual operators working properties which have no connection with the lands of the transportation company.

A detailed description and history of each of the carrying roads is impracticable in an article so short as the present, and only a few of the salient points in connection with each will be referred to. As the map, Pl. VI, shows, six of the roads enter only the Wyoming field. Three of them enter all of the fields. Two of them enter all of the fields but the Northern, and one is confined to the Lehigh region.

According to the present constitution of Pennsylvania, a railroad company can not mine and sell coal. Hence, excepting where the charters antedate the present constitution, the coal-carrying roads are theoretically separate corporations from the mining corporations, commonly referred to by the same name. This distinction may be carried out theoretically and legally, but for all practical purposes the coal-carrying roads and their corresponding coal companies are one and the same thing, as the stock of the coal company is usually exclusively controlled by the railroad, and none but a lawyer can tell where the coal company leaves off and the railroad corporation begins.

The Delaware, Lackawanna and Western Railroad Company has the right to mine, transport, and sell coal. Hence, it has not even a theoretically separate coal company. Its operations are mainly in the immediate vicinity of Scranton and along the northern bank of the Susquehanna, between Pittston and Plymouth, and also in the neighborhood of Nanticoke, where it has a magnificent, untouched field of coal, awaiting development.

The road has no tenants operating mines upon its lands, but it does ship the output of a number of individual operators. The main line of the railroad crosses the Lackawanna basin at Scranton, which is the headquarters of the coal department and where there are extensive yards and shops. A branch known as the Lackawanna and Bloomsburg Division extends from Scranton, down the Susquehanna River, to Northumberland, where it connects with the Pennsylvania Railroad. This division is equipped for handling a large coal tonnage.

The Delaware and Hudson Canal Company operates its coal department under the same name, and its operation extends from the upper end of the northern field above Carbondale to Plymouth. In the upper portion of this territory mining has been carried on since 1829, this company being one of the oldest of the anthracite corporations. Until the close of 1898 most of its coal was shipped over the gravity road from Carbondale to Honesdale, and thence by canal to Rondout on the Hudson, but at the close of the season of 1898 the gravity road and canal were abandoned and a standard-gage road was built between Carbondale and Honesdale, where the Delaware and Hudson delivered its coal to the Erie. A portion of the tonnage also passes over the Jefferson Branch of the Erie from Carbondale to Nineveh, where it is taken by the main line of the Delaware and Hudson.

The Erie and Wyoming Valley Railroad superseded the old gravity road of the Pennsylvania Coal Company. It was built to connect the mines of the Pennsylvania Coal Company, and to transport its coal from Pittston to Hawley, where it is delivered to the Erie. This road was the nucleus about which the proposed Individual Operators' Railroad, the Delaware Valley and Kingston, was to be built, and when it and the Pennsylvania Coal Company were absorbed by the Erie in January, 1901, this proved the deathblow of the proposed new coal road. The coal properties of the Pennsylvania Coal Company now working are near Pittston and Dunmore, while there are reserves north of Scranton.

The Erie Railroad Company designates its coal company the Hillside Coal and Iron Company, and its principal operations are at the extreme northern end of the Lackawanna Valley, near Forest City, Jermyn, Mayfield, and Peckville, although it also has collieries at Moosic and Avoca, and it owns the Butler colliery at Pittston. The Erie Railroad does not extend south of Carbondale, but the coal from these collieries is transported over the Delaware and Hudson to Carbondale or over the Erie and Wyoming to Hawley, were it is taken by the Erie. It also transports a large amount of coal for individual operators and for the Delaware and Hudson. The Pennsylvania Coal Company and the Erie and Wyoming Valley Railroad are now owned and operated by the Erie.

The New York, Ontario and Western Railway Company is nominally only a coal carrier, but the New York and Scranton Coal Company, and the Scranton Coal Company are generally considered as the coal department of this road. It connects with the Central Railroad of New Jersey in Scranton, and within the last year it has been a heavy buyer of coal properties, most of which are north of Scranton, its principal properties being the collieries formerly owned by the Lackawanna Iron and Steel Company, by the Elk Hill Coal and Iron Company, and by the Pancoast Coal Company.

The New York, Susquehanna and Western Railroad Company has been absorbed by the Erie.

The Pennsylvania Railroad Company's mines in the Wyoming region are operated under the name of the Susquehanna Coal Company, and its properties are near Nanticoke and Glen Lyon, at the extreme southern end of the Wyoming field. This road enters the western-middle field by the branch running from Shamokin to Sunbury, and operates mines between Shamokin and Mount Carmel by its subcorporations, the Mineral Railroad and Mining Company, and the Union Coal Company. It also has branch lines running from its north and west branch into the Schuylkill and Lehigh regions, and it has traffic arrangements for transporting coal over these branches.

The Lehigh Valley Railroad Company conducts its mining operations under the name of the Lehigh Valley Coal Company, which was organized in 1881. The company operates mines in all of the coal fields, and in addition to the large output of its own mines the railroad is an extensive carrier of coal mined on its own land by its tenants and also by individual operators mining upon lands which do not belong to the railroad company. The main line of the railroad runs through the anthracite field from Mauch Chunk to Pittston, but the Lehigh and Schuylkill districts, as far as Mount Carmel, are a perfect network of branch roads, known as the Coal Branches.

The Delaware, Susquehanna and Schuylkill Railroad is operated by the Cross Creek Coal Company, commonly known as the Coxe Estate. It connects all of the collieries of this estate, and has trackage arrangements by which it carries its coal to market over the Lehigh Valley Railroad, but with its own engines. The mines of the Cross Creek Coal Company are in the Lehigh region, about Drifton.

The Central Railroad of New Jersey mines under the title of the Lehigh and Wilkesbarre Coal Company, with headquarters at Wilkesbarre. It operates collieries in the Wyoming region and has interests in the Lehigh region near Audenried. A branch of the railroad traverses the Panther Creek basin and handles the product of the Lehigh Coal and Navigation Company. The company has large undeveloped tracts of excellent coal land between Wilkesbarre and Nanticoke. It uses the Delaware and Hudson tracks from Wilkesbarre to within 4 miles of Scranton, which city it enters over its own tracks, and connects with the New York, Ontario and Western. In January, 1901, this road was absorbed by the Philadelphia and Reading.

The Philadelphia and Reading Railroad operates its mines through the Philadelphia and Reading Coal and Iron Company. It is the most extensive owner of coal lands and the heaviest miner of coal of all the operators. Its headquarters are in Pottsville and its operations are almost exclusively in the Schuylkill region, including both the southern and the western-middle fields. The railroad traverses the Schuylkill region from north to south and from east to west and has numerous branches reaching to its widely distributed collieries.

All of the roads mentioned above have an outlet into New York City, either directly or through Perth Amboy, Port Reading, or some other New Jersey port. The New England market is supplied by rail or by water transportation in barges to Boston and the Sound ports. The coal for lake shipment to Chicago, Milwaukee, Detroit, and the other western distributing points is mainly shipped through Buffalo, and in smaller amounts through Erie. The Lehigh Valley, Delaware, Lackawanna and Western, Erie, and Pennsylvania go to Buffalo, while the Pennsylvania reaches Erie over its Philadelphia and Erie branch Such small amounts as go to western and central Pennsylvania are also carried by the Pennsylvania Railroad, which road also over the Northern Central takes a large portion of the anthracite supply to Baltimore, Washington, and points farther south. Philadelphia is supplied by the Philadelphia and Reading and by the Pennsylvania, and from here some coal is also shipped southward over the Baltimore and Ohio.

In the Bond Record for August, 1896, Mr. William Griffith gives a table showing the relative holdings of coal properties of the several railroads at that time. Many changes have taken place in these holdings within the last two years and others are still in progress, so that it is not practicable to give such a table at the present time. The individual operations are being rapidly absorbed by the coal-carrying corporations.

INDIVIDUAL OPERATORS.

Although the greater part of mining of anthracite has been done by the various coal companies controlled by the transportation companies, a very considerable amount has been mined by individual operators, as those persons are called who work either their own properties or properties leased from others or from railroads. Such individual properties are of course dependent upon the transportation companies for the shipment of their coal, and from the beginning of the anthracite mining industry there has been a contention between the individual operators and the railroads over the rates of freight charged. It has been largely through the efforts of the individual operators to secure reduced rates that one after another of the present anthracite railroads has been built to and extended into these regions.

The history of this contention was well given by Mr. Henry S. Fleming, secretary of the Anthracite Coal Operators' Association, in the Association Letter for December, 1900, from which an extract is given below:

In the earlier days of the anthracite industry there were in only a few individual cases contracts by which the railroads, or the coal companies operated by them, purchased coal from independent operators. The Lehigh Valley and several others had an arbitrary freight rate, which was advanced or decreased as the average price at tide water changed. The Delaware, Lackawanna and Western and the Delaware and Hudson, both of whom handled coal from independent operators, took it on a sliding scale under the labor-basis contract. The various contracts and rates of freight netted the operators from 40 to 45 per cent of the tide price, and less than this in the case of certain competitive points to which the arbitrary freight was charged.

When the New York, Susquehanna and Western was projected into the Wyoming region its promoters agreed to buy coal from the independent operators and pay 50 per cent of the tide-water price; but there was a long and hard fight before it was built, and its completion was delayed until 1894, though prior to that time the company had been buying and shipping coal under its contracts.

In 1888 Coxe Brothers & Co., the largest shippers among the individual operators, appealed to the Interstate Commerce Commission against the rate charged against their coal by the Lehigh Valley Railroad Company. During the progress of the hearings the railroad company reduced its freight rate slightly. The decision, announced in March, 1891, was that many of the points at issue were outside the scope of the Commission, and that the rate then established should not be advanced.

In 1890 the New York, Ontario and Western Railway built an extension into the upper Wyoming region after securing a guaranty of sufficient tonnage, offering to transport the coal for 40 per cent of the tide price and later agreeing to buy the output and pay 55 per cent of the f. o. b. price. Other railroads gradually made a similar advance. In 1892, after a series of consultations between the president of the Reading Railroad and a committee representing the individual operators, a contract was drawn up giving 60 per cent of the tide price to the operators, and this was entered into by the various companies then under the control or influence of the Reading.

These contracts extended for seven years and expired in 1899. In 1898, after repeated efforts had been made to secure the promise of their renewal on more favorable terms, each failing any definite result, the individual operators organized the New York, Wyoming and Western Railway Company; surveyed a line from the Wyoming region to tide water; bought several thousand tons of rails; secured right of way, a satisfactory tide terminal, and began construction. Upon this, negotiations were opened by the railroads, culminating, after nearly a year, in a satisfactory plan, which was begun, but not completed. After this, the opportunity occurring, the interests of the operators were consolidated with the Pennsylvania Coal Company, the bed of the abandoned Delaware and Hudson Canal was purchased, and the Delaware Valley and Kingston Railway Company incorporated.

The contracts upon which this new road was to buy the operators' coal gave to the latter 65 per cent of the tide-water price; or, in other words, reduced the freight rate from one-half the f. o. b. price, which it was prior to the 1892 contracts, to but little over one-third, besides making even more material concessions in pea coal and the smaller sizes, and giving an opportunity for more days work each year than had been possible under the former arrangement. Under such conditions the operators had hoped to be able to market their coal at a lower price, thus reducing the cost to the public while receiving themselves the benefit of the increased output.

The existing anthracite companies opposed this new railroad, both by endeavoring to obstruct its right of way and by a legal fight. But as one after another decision resulted favorably to the new enterprise it became apparent that other steps were necessary to be taken.

Therefore the Pennsylvania Coal Company was bought by Messrs. J. Pierpont Morgan & Co., of New York City, in January, 1901, at an increase of 752 per cent upon the par value of the stock. This property was immediately sold to the Erie Railroad, and thus the contest was closed. Almost immediately after this transaction a number of other individual properties were bought up by different railroads, and there was more or less of a scramble on the part of certain railroads to secure properties and upon the part of certain individual operators to sell out, as it was thought by some that an attempt would be made to force out the remaining individual operators.

FREIGHT RATES.

In considering the subject of freight rates on anthracite it must be borne in mind that the distances over which the greater part of the product is hauled are comparatively short, as is shown by the following table, which gives the distances from the principal mining centers to the chief points of consumption:

Distances from mining centers to chief points of consumption.

	Miles.
Scranton to Chicago	800
Scranton to Buffalo, Delaware, Lackawanna and Western	266
Wilkesbarre to Buffalo, Lehigh Valley	262
Pottsville to New York, via Philadelphia, Philadelphia and Reading	184
Wilkesbarre to New York, Lehigh Valley	177
Wilkesbarre to New York, Central Railroad of New Jersey	174
Scranton to New York, Delaware, Lackawanna and Western	145
Pottsville to New York, via Philadelphia, Pennsylvania	184
Shamokin to New York, via Sunbury, Pennsylvania	267
Carbondale to New York, via Lackawaxen, Erie	155
Carbondale to New York, via Susquehanna, Erie	231
Scranton to New York, New York, Ontario and Western	214
Wilkesbarre to New York, New York, Susquehanna and Western	167
Pottsville to Philadelphia, Philadelphia and Reading	94
Wilkesbarre to Perth Amboy, Lehigh Valley	160
Scranton to Cornwall, New York, Ontario and Western	161
Pittston to Newburgh, via Erie, Delaware and Hudson	144
Pittston to Jersey City, via Erie, Delaware and Hudson	179
Carbondale to Newburgh, Erie	180

The average rates on anthracite, as given by the Letter of the Anthracite Coal Operators' Association for November, 1898, were as follows:

Average rate on coal to Perth Amboy by rail, per ton of 2,240 pounds.

Year.	From Lehigh and Mahanoy region.			From Wyoming region.		
	Prepared sizes.	Pea and buckwheat.	Culm.	Prepared sizes.	Pea and buckwheat.	Culm.
1875	$2.25			$2.51		
1876	1.90			2.17		
1877	1.41			1.63		
1878	1.68			1.88		
1879	1.19			1.40		
1880	1.72			1.93		
1881	1.90			2.11		
1882	1.88			2.09		

Average rate on coal to Perth Amboy by rail, per ton of 2,240 pounds—Continued.

Year.	From Lehigh and Mahanoy region.			From Wyoming region.		
	Prepared sizes.	Pea and buck-wheat.	Culm.	Prepared sizes.	Pea and buck-wheat.	Culm.
1883	$1.90	....	....	$2.11	....	....
1884	1.80	$1.57	$1.57	1.92	$1.66	$1.66
1885	1.52	1.32	1.32	1.61	1.41	1.41
1886	1.40	1.20	1.20	1.49	1.29	1.29
1887	1.57	1.41	1.41	1.67	1.51	1.51
1888	1.77	1.48	1.35	1.87	1.58	1.45
1889	1.73	1.40	1.20	1.79	1.46	1.26
1890	1.70	1.40	1.20	1.75	1.45	1.25
1891	1.70	1.40	1.20	1.75	1.45	1.25
1892	1.75	1.45	1.25	1.78	1.48	1.28
1893	1.74	1.44	1.24	1.74	1.44	1.24
1894	1.57	1.40	1.30	1.57	1.40	1.30
1895	1.50	1.40	1.35	1.50	1.40	1.35
1896	1.52	1.40	1.26	1.52	1.40	1.26
1897	1.55	1.40	1.20	1.55	1.40	1.20

The following data in regard to freight rates are compiled largely from the letters of the Anthracite Coal Operators' Association during the last three years.

In 1897 the Philadelphia and Reading rates for comparatively short hauls were as follows:

Philadelphia and Reading freight rates in 1897.

Schuylkill Haven to—	Prepared sizes.			Pea.		Buckwheat.	
	Miles.	Rate.	Per ton per mile.	Rate.	Per ton per mile.	Rate.	Per ton per mile.
			Mills.		*Mills.*		*Mills.*
Reading	31	$1.40	45.1	$1.25	40.3	$1.25	40.3
Pottstown	53	1.55	29.2	1.40	26.4	1.25	23.5
Phoenixville	65.5	1.60	24.4	1.40	21.3	1.25	19.0
Marion	74	1.70	22.9	1.40	18.6	1.25	16.8
Philadelphia	89.7	1.70	18.9	1.40	15.6	1.25	13.9

During the same period the Delaware, Lackawanna and Western charges were as follows:

Delaware, Lackawanna and Western freight rates in 1897.

	Miles.	Rate.	Per ton per mile.
			Mills.
Pittston to Binghamton, N. Y	71	$1.65	23.2
Pittston to Elmira, N. Y	128	1.75	33.6
Pittston to Corning, N. Y	144	1.95	11.5
Pittston to Syracuse, N. Y	150	2.05	13.6
Pittston to Oswego, N. Y	185	2.10	11.3
Pittston to Buffalo, N. Y	274	2.25	8.2
Pittston to Morristown, N. J	124	1.55	12.5
Pittston to Paterson, N. J	139	1.60	11.5
Pittston to Orange, N. J	142	1.60	11.2
Pittston to Newark, N. J	146	1.60	10.9
Pittston to Hoboken, N. J	154	1.60	10.3

A comparison between the rates charged for anthracite and bituminous at about the same time is given in the following table:

Comparison of bituminous and anthracite freight rates.

	Miles.	Freight.	Per ton per mile.	Selling price.
			Mills.	
Bituminous coal	500	$1.25	2.5	$2.00
Anthracite (buckwheat)	154	1.60	10.3	1.80
Anthracite (stove)	154	1.60	10.3	3.70

The comparative rates upon anthracite coal, bituminous coal, and grain during the season of 1899 were as follows:

Comparative rates upon anthracite and bituminous coal and grain in 1899.

	Value at shipping point, per net ton.	Miles transported.	Total freight.	Rate per ton per mile.	From—	To—
Grain	$28.00	912	$3.40	3.7	Chicago	New York.
Soft coal	.75	418	.92	2.9	Kanawha	Newport News.
Anthracite	2.00	800	3.12	3.9	Scranton	Chicago.
Do	2.00	145	1.47	10.1	Scranton	Hoboken.
Soft coal	.75	957	2.30	2.4	Gauley	St. Paul.

The freight rates charged for carrying anthracite are greatly in excess of the average rates upon similar materials, and these rates have been undoubtedly disadvantageous to the individual operators.

From 1890 to 1898 there was an average reduction in freight rates upon all classes of merchandise carried by the railroads in the Middle States of 22.7 per cent, while during the same period the average reduction on anthracite was 7.3 per cent. These high rates particularly affected the steam sizes of coal, which come into direct competition with bituminous coal, upon which the freight rates were so much less. During 1898 the rates on bituminous varied from 1.5 to 2.3 mills per ton mile. Upon anthracite during the same period the rates were 7 to 14.9 mills per ton mile.

The barge rate from New York to tide ports in New England was in 1898 as follows:

Barge rates per ton from New York to New England points.

	Cents.
Barge rates	50
Unloading, etc.	25
Insurance	2
Screening	10
Total	87

MARKETING OF ANTHRACITE.

With few exceptions there has been little improvement in the handling of anthracite by the retailers. The railroad cars, loaded with coal, are pushed on a trestle, and the coal is dumped into the proper bin. Coal from barges is unloaded with wheelbarrows, or, in some cases, by a steam-power crane, to the wharf, whence it is hauled to the retail yard and then to the consumer in carts, usually carrying 1 ton, sometimes 2 tons.

The Anthracite Coal Operators' Letter of February, 1899, gave the following costs of marketing anthracite, based upon delivery from Madison avenue and Fifty-ninth street, New York City, as a distributing point, the coal being delivered to this central distributing point from yards along the East and North rivers, between Brooklyn Bridge and One hundred and thirty-eighth street. A reduction of 25 cents per ton is usually made in lots of 5 tons or more, and an extra charge of 25 cents per ton when the coal had to be carried into a cellar.

Cost of marketing anthracite.

	Cost alongside dealer's wharf.	Dealer's selling price, delivered on sidewalk.	Difference.
Lykens Valley:	*Ton of 2,000 lbs.*	*Ton of 2,000 lbs.*	
Stove	$4.55	$6.75	$2.20
Chestnut	4.24	6.75	2.51
Schuylkill red ash:			
Egg	3.52	5.50	1.98
Stove	3.92	5.64	1.72
Chestnut	3.61	5.64	2.03
Pea	2.18	3.25	1.07
Schuylkill white ash:			
Broken	3.03	5.20	2.17
Egg	3.17	5.20	2.03
Stove	3.39	5.20	1.81
Chestnut	3.30	5.20	1.90
Pea	2.14	3.50	1.36
Lackawanna white ash:			
Broken	2.94	4.75	1.81
Egg	3.12	4.75	1.63
Stove	5.30	5.05	1.75
Chestnut	2.99	4.95	1.96
Lehigh white ash:			
Broken	2.94	5.05	2.11
Egg	3.17	5.05	1.88
Stove	3.39	5.15	1.76
Chestnut	3.17	5.10	1.93
Pea	2.14	3.45	1.31
Buckwheat	1.87	2.95	1.08
Lehigh red ash:			
Broken	3.17	5.55	2.38
Egg	3.39	5.55	2.16
Stove	3.61	5.60	1.99
Chestnut	3.39	5.50	2.11

The cost of handling coal at yards where the facilities are fairly good is given in the same article as follows:

Cost per ton of handling coal at yard.

	Cents.
Unloading from barge into coal pockets	10
Storing and screening	4
Loss by screening	10
Average cost of carting to consumer	32
Clerical work	5
Incidentals, rent, interest, and losses	14
Total	75

At exceptionally well located yards this cost may be reduced to 50 cents per ton, while at yards disadvantageously located, it may be as much as 95 cents. The same Letter for May, 1899, gives the limits of costs of handling coal by the retailer as varying between 65 cents and $1.40 per ton.

EXPORT OF ANTHRACITE.

The subject of the export of anthracite has been investigated by agents sent abroad by the railroad companies, and by the individual operators, but the reports returned have not been encouraging, and no definite efforts have been put forth to materially increase the export business. A comprehensive report upon this subject is given by Mr. Fleming in the Letter of the Anthracite Operators' Association for July, 1899, page 7.

The subject of anthracite coal is entirely too broad to be treated in the limited space allotted to the present article, and the writer has therefore been compelled very greatly to curtail the available data and to present only such portions as seem to be of most general interest. In compiling this, the original source of much of the data given are the very excellent and elaborate articles upon anthracite coal by Mr. William Griffith, which appeared in the Bond Record during 1896, the Association Letters of the Anthracite Coal Operators' Association, and the several reports of the Second Geological Survey of Pennsylvania, by Ashburner, Smith, Chance, and others. It has been impossible to give credit in every instance to the original source, and this has been attempted only when direct quotations have been used.

LITERATURE.

The following list of books and periodicals will be of value to those who wish to look into the subject more completely:

Anthracite coal, by William Griffith: The Bond Record, Feb'y–Aug. (Incl.), 1896.

Association Letters of the Anthracite Coal Operators' Association.

Reports of the Second Geological Survey of Pennsylvania: Vols. A, AA, AC; Coal Flora P; Summary Final Report; Annual Report, 1885; Annual Report, 1886, Part 3.

The Coal and Metal Miners' Pocket Book.

Mines and Minerals, Scranton, Pa.

The Mineral Industry, by R. P. Rothwell, Vols. 1 to 9.

The Coal Trade, by F. E. Saward, Vol. 1 to 27.

Coal: Its Antiquity, Discovery and Early Development in the Wyoming Valley, a paper read before the Wyoming Historical and Geological Society, by Geo. B. Kulp.

The Engineering and Mining Journal, New York City.

The Anthracite Coal Industry, by Peter Roberts, Ph. D.

THE NORTHERN APPALACHIAN COAL FIELD

BY

DAVID WHITE, MARIUS R. CAMPBELL, AND ROBERT M. HASELTINE

CONTENTS.

ILLUSTRATIONS.

THE NORTHERN APPALACHIAN COAL FIELD.

By David White, Marius R. Campbell, and R. M. Haseltine.

GEOGRAPHIC RELATIONS.

The Appalachian coal field extends from the northern border of Pennsylvania southwestward, a distance of 800 miles, to central Alabama. Its greatest width is about 180 miles, near its northern end, from which it tapers gradually southward to less than 20 miles in Tennessee and then expands to about 80 miles in Alabama. It embraces portions of 9 States, and has a total estimated area of 70,000 square miles. It is by far the most important of the bituminous coal fields of the United States in extent, in the quality of its coal, the number and thickness of workable beds, state of development, and in importance and accessibility of its markets.

While the field is a unit in respect to its chief characteristics, it has been subdivided for convenience of treatment into a northern and southern field. The former, considered in this paper, embraces that portion of the field which lies in the States of Ohio, Pennsylvania, Maryland, and West Virginia.[a]

GEOLOGIC RELATIONS.

The coal-bearing formations of the Northern Appalachian field belong to the Carboniferous system. They consist for the most part of shales, sandstones, and conglomerates, with occasional beds of limestone, fire clay, and coal. In general the formations show a gradual thinning from the eastern margin of the field westward, and there is also a decrease in the number and thickness of the coal beds in the same direction. This westward thinning of both rock formations and coal is observable only in a general way, however, and many local exceptions are found.

The eastern margin of the field borders upon the belt of steeply folded strata that forms the Appalachian Valley, and along this margin

[a] The absence of a section on West Virginia is due to the illness of the geologist to whom that portion of this paper was assigned. A report on the West Virginia coal field has been prepared by the State geological survey and is said to be now in press.—C. W. H.

the coal-bearing formations have also been considerably folded. The folding becomes less pronounced toward the west, and in the central

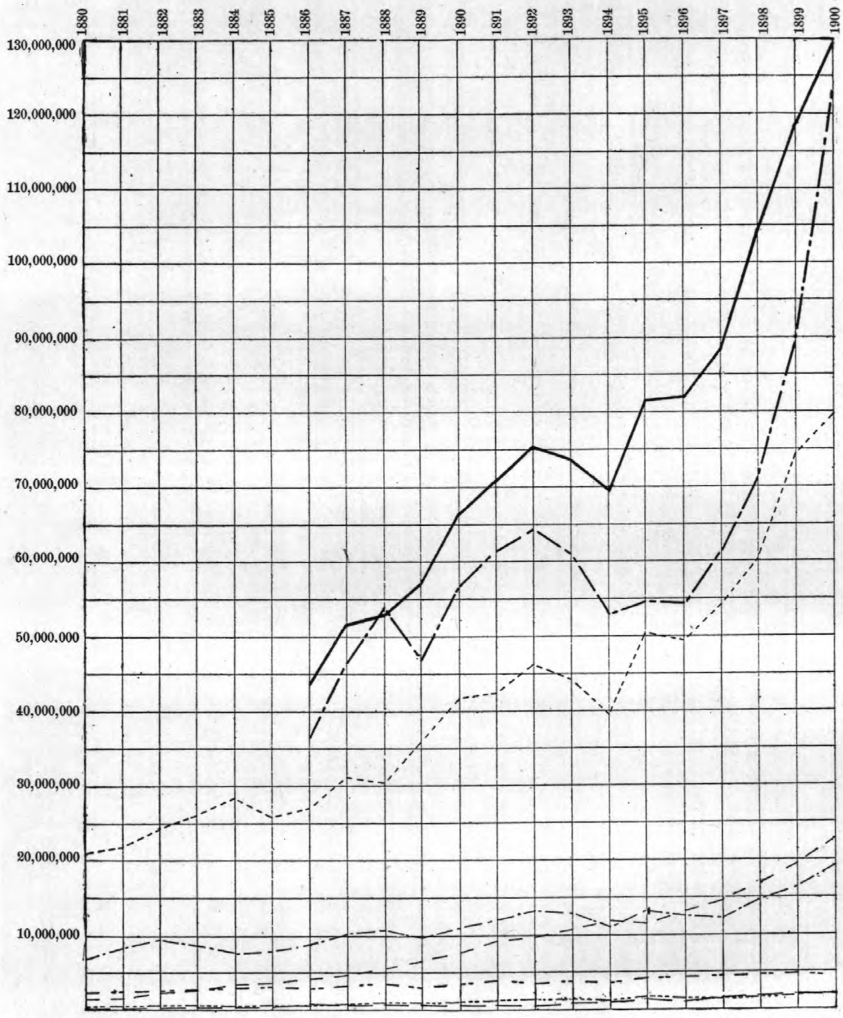
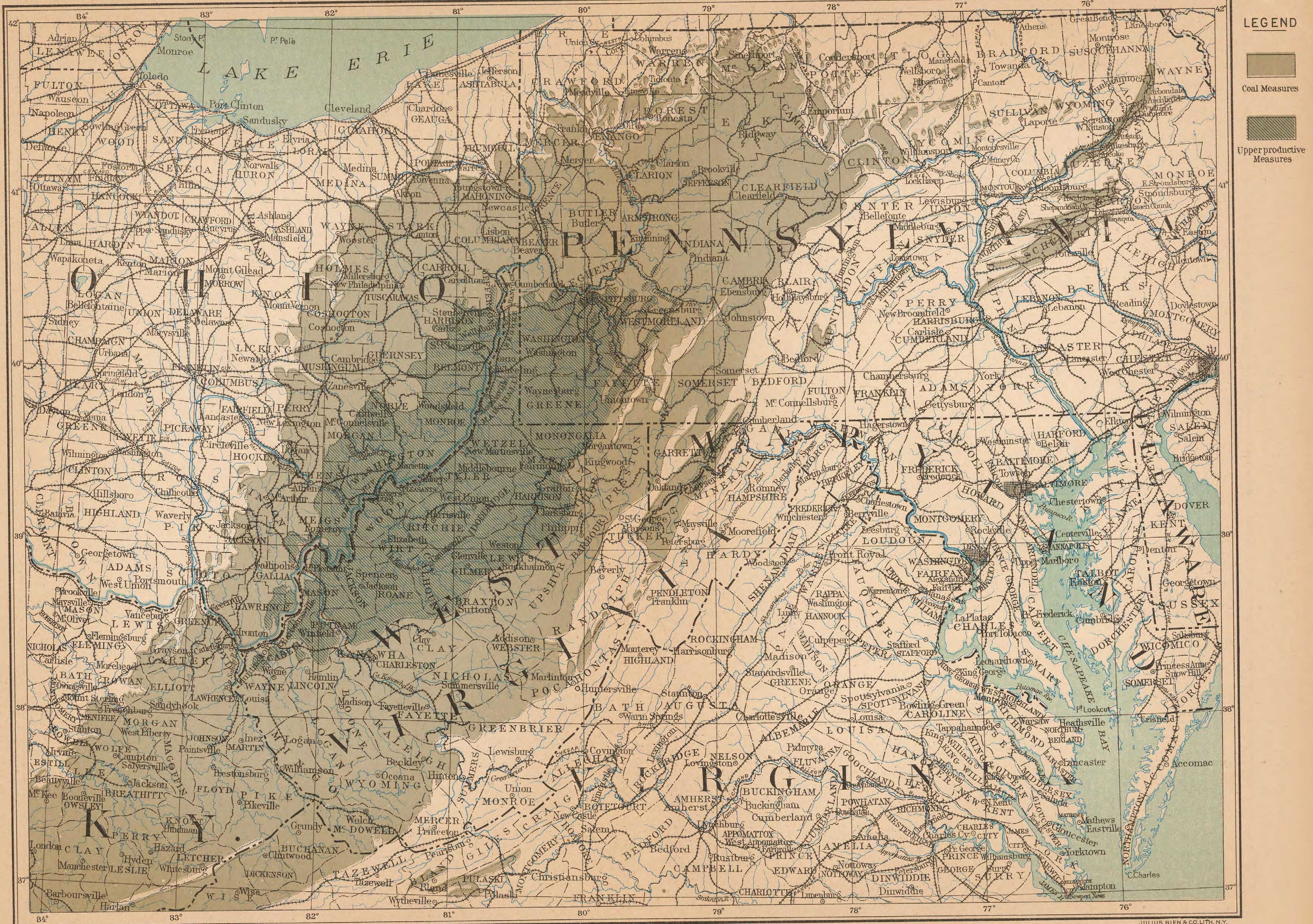


FIG. 20.—Production of coal in the Northern Appalachian field, including Pennsylvania, Ohio, Maryland, West Virginia, eastern Kentucky, and Virginia.

----- Pennsylvania. —·—·—·— Ohio. —··—— Maryland. — — — — West Virginia. ···—···— Eastern Kentucky. —— —— Virginia. ▬▬▬ Total production. ▬ ▪ ▬ Total value. Scale: 5,000,000 tons to the square, $5,000,000 to the square.

and western portions of this field the strata are either practically horizontal or occur in very gentle undulations.



THE NORTHERN APPALACHIAN COAL FIELD

Scale

25 0 25 50 75 100 MILES

THE BITUMINOUS COAL FIELD OF PENNSYLVANIA.

By David White and Marius R. Campbell.[a]

GEOGRAPHIC RELATIONS.

The bituminous coal field of Pennsylvania embraces the northeastern end of the great Appalachian series of the Coal Measures. It includes an area of about 12,200 square miles, lying chiefly in the western part of the State, and spreading from Ohio, West Virginia, and Maryland northeastward toward New York. The coal-bearing rocks cover practically the whole of Greene, Washington, Allegheny, Westmoreland, Beaver, Lawrence, Butler, Armstrong, Jefferson, Indiana, Clearfield, and Cambria counties, and the greater portions of Fayette, Somerset, Elk, Clarion, and Mercer counties, besides parts of Crawford, Venango, Forest, Warren, McKean, Cameron, Blair, Huntingdon, Bedford, Fulton, Center, Clinton, Potter, Lycoming, Tioga, and Bradford counties.

The boundary of the general Coal Measures area is extremely irregular. The main area is limited on the west by an irregular line running from the northwest corner of McKean County, through Warren and Crawford counties, to the southwest corner of Crawford County, and on the east by the Allegheny Front. In the extreme northwestern part of this area the Coal Measures occur in outlying patches capping high knobs and ridges. Farther east, where the synclinal structure is more marked, the small detached tracts are arranged in rude series in alignment with the ill-defined synclinal finger lobes. Certain of the most northeastern and isolated areas, as the Bernice (semianthracite) basin and the Barclay and Blossburg basins, are so far detached from the main territory to which they belong that they are generally treated as distinct basins or subbasins. Besides the main area, with its northern marginal fringe of more or less isolated small areas, there is what is known as the Broadtop field or basin in Huntingdon and Bedford counties. This is about 50 square miles in extent, and is about 30 miles east of the Allegheny Front.

GEOLOGIC STRUCTURE.

The bituminous coals of Pennsylvania belong to the Upper Carboniferous. The lowest coals lie within the Pottsville, the basal formation of this series, and the highest are contained in the Dunkard forma-

[a] The sections on the Monongahela and Dunkard formations (pages 175–182) were prepared by Mr. Campbell, the rest of the report by Mr. White.

tion, which includes the latest Paleozoic beds recognized in the Appalachian trough.

The structure of the coal fields conforms in a general way to the system of Appalachian folding in long northeast-southwest waves, locally modified more or less by minor cross structures. In the northwestern part of the area the strata gently undulate, with extremely slight dips, generally of but a few feet to the mile, but in passing eastward the waves increase to well-marked billows along the eastern margin of the main body of the coal field. Beginning at the eastern margin of this principal area we have six well-marked synclines, which, passing westward, are respectively designated as the first to the sixth bituminous basins. The axes separating the best defined of these basins are known in the southern part of the State as the Viaduct, Laurel Hill, and Chestnut Ridge anticlines. The Laurel Hill and Chestnut Ridge arches, which enter from West Virginia and western Maryland, are most distinct, bringing Devonian rocks to the surface for some distance within the State of Pennsylvania, and although they gradually die out while traversing the coal field their axes are more or less distinct across the entire territory.

The existence of the northeastwardly extending finger lobes and isolated patches of Coal Measures which fringe the northern area of the great field are concomitant results of (1) the intersection of the main system of undulations by the minor irregular cross folds; (2) the deep erosional dissection of the Allegheny Plateau to the northward, and (3) the gradual rise of the strata to the northeastward.

In the shallow patches and little basins which attain in some instances an altitude of over 2,000 feet and which comprise the northern fringe of the field, only the lowest and oldest of the coal-bearing formations are present; but in passing southward the deepening of the synclines by pitching of the axes causes the gradual blending of the isolated areas and the coalescence of the lobes into the main field which sweeps southward and westward to the State boundaries. At the same time the thickness of the coal-bearing rocks increases with the introduction of higher formations, so that in the deepest portions of the coal field in Washington and Greene counties the coal-bearing formations attain a thickness of about 2,600 feet.

Throughout four-fifths of the Coal Measures territory the thickness of the Upper Carboniferous rocks is less than 1,000 feet, while throughout one-third of the entire area the depth is less than 500 feet.

The Broadtop field of Huntingdon and Bedford counties lies in the zone of most intense Appalachian folding. Accordingly, the structure in this field, in strong contrast to that in the other bituminous basins, is complicated, involving close folding similar to that found in the Southern and Middle Anthracite coal fields to the eastward.

In general the bituminous field of this State is remarkable for the almost total absence of structural faults such as are known to occur to the east of the Allegheny escarpment[a] and in the coal fields of the Southern Appalachian region. The faults to the west of the escarpment lying, so far as recognized, along the first basin in Clearfield, Center, and Cambria counties, are probably less than 10 in number and of very slight extent, the greatest displacement, that at Moshannon, being less than 90 feet.

West of the zone of small faults, which lies near the Allegheny Front, the Coal Measures are practically unbroken. The only difficulties encountered in mining are local squeezing or rolling, irregularities of deposition, and contemporaneous erosion, such as are to be found in the coal formations of all parts of the world.

NUMBER OF WORKABLE BEDS.

The Upper Carboniferous in the bituminous coal fields of Pennsylvania has been divided chiefly on the basis of the lithology, though partly from an economic standpoint, into five subdivisions[b] in descending order as follows:

Upper Carboniferous formations in the bituminous coal fields of Pennsylvania.

Formation.	Average thickness.
	Feet.
5. Dunkard (Upper Barren), XVI	1,100
4. Monongahela (Upper Productive), XV	360
3. Conemaugh (Lower Barren), XIV	600
2. Allegheny (Lower Productive), XIII	280
1. Pottsville (Seral Conglomerate), XII	270

The principal sources of coal are the Allegheny and Monongahela formations, from which over 95 per cent of the output is derived, although shipping mines are also located in the Pottsville and Conemaugh formations, the mines of the Pottsville being situated on the very extensive outcrops near the margins of the coal fields, while those of the Conemaugh are confined almost entirely to the area of this formation in the First basin in Somerset County, near the southern boundary of the State.

The composition and sequence of the members and formations of the Upper Carboniferous in the bituminous regions of the State are shown in the accompanying generalized sections (figs. 21–25). Owing to the changes in lithology and the irregularity of several of the coals

[a] The Tipton Run coals, in Blair County, lying east of the Allegheny escarpment, are in a very small faulted block, the displacement of which is about 1,200 to 1,400 feet.

[b] These subdivisions are designated by some geologists as series.

and limestones, it is impracticable to attempt to show all the economic beds in a single compiled section, or all the key rocks, since they are rarely present even in a single formation in typical thickness at any locality. The section representing the Pottsville formation (fig. 21) is generalized from the sections in the northwestern counties; the Allegheny (fig. 22) represents the general section of the Allegheny Valley; the Conemaugh (fig. 23) the region of Fayette County; while the sections of the Monongahela and Dunkard formations (figs. 24, 25) are somewhat generalized from the sections in the southwestern corner of the State. The economic changes in the formations in different areas will be noted in the observations on the coals.

In the discussion of the distribution of the coals the areal estimates are of necessity based for the most part on the county geological maps, and are, therefore, to be regarded as crude and but very roughly approximate. No estimate of the coal contents that will be sufficiently accurate to be satisfactory can be prepared until the beds shall be more accurately mapped on a topographic base.

In the following pages the geographic distribution of the coals will be considered by counties. The data given therein are mainly compiled from the county reports and the very excellent condensation and revision given by Mr. E. V. d'Invilliers, in the Summary Final Report, Vol. III, Pt. II, published by the State in 1894. It will therefore be understood that the material, including the analyses, is drawn chiefly from the report volumes of the Second Geological Survey specially relating to the respective counties, and constant reference to these reports by footnotes will accordingly be omitted.

DESCRIPTIONS OF WORKABLE BEDS.

POTTSVILLE FORMATION, OR SERAL CONGLOMERATE (XII).

GENERAL CHARACTERS AND THICKNESS OF THE FORMATION.

In the bituminous basins of Pennsylvania the Pottsville formation (XII), the lowest main subdivision of the Upper Carboniferous, lies unconformably on the beds of the Lower Carboniferous. Throughout the greater part of its present area it rests on the red and green shales of the Mauch Chunk formation (XI). But northwest of a line drawn through McKean, Forest, and Clarion counties it is imposed on yellowish-green shales and sandstones, which possibly represent merely a different phase or a different level of the Mauch Chunk, although it is probable that in the extreme northwest they are of earlier date.

As a whole the Pottsville is a coarsely arenaceous member, from 160 to 350 feet thick in the bituminous regions of the State, composed of conglomerates, sandstones, shales, and irregular coals, and containing local developments of limestone, iron ore, and very valuable highly refractory fire clays. The general constitution of the formation and the thickness of its members in the western portion of the State may be seen in the general section compiled from measurements in Mercer County.

The salient feature of this formation in western Pennsylvania, as in Ohio and Maryland, is the presence over most of its area of three sandstones which inclose two intermediate more or less carbonaceous shaly groups, the Sharon shale group and the Mercer group. The basal member,[a] known as the "Sharon conglomerate," the "Olean conglomerate," or "Garland conglomerate," a massive conglomerate of great variability as to thickness, is nearly always present, constituting a well-marked base of the Upper Carboniferous.[b] It, together with the Conoquenessing and Homewood sandstones, all of which are relatively close together, strongly affect the topography of the regions. They form the raised rims of the Coal Measures areas, constitute the crest of the Allegheny front, and are chiefly responsible for the extent of the superposed Allegheny coal-basin beds as well as for the survival of the fringing patches along the northern margin of the coal field.

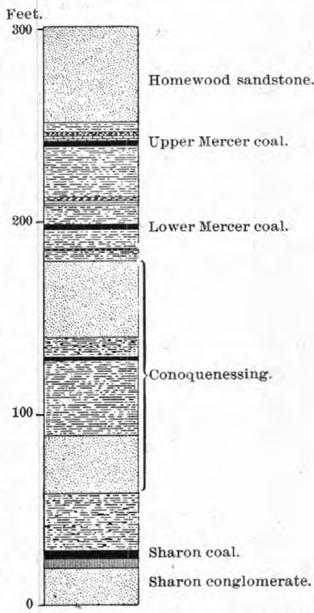


FIG. 21.—Section of the Pottsville formation in Mercer County (after I. C. White).

In Pennsylvania as well as in other portions of the Appalachian trough the Pottsville is noted for the variability of its members in thickness, composition, and character, and this irregularity pertains to the coals as well as to the other members of the formation. The workable coals of the formation are confined to the Sharon and the Mercer groups. The former contains but one commercial coal, the Sharon coal, in western Pennsylvania. The Mercer contains a number of sporadic and locally workable beds so restricted in vertical limit, sometimes to less than 30 feet, and so variable in position that they may be treated as representing a single horizon.

[a] Although the Sharon conglomerate forms the base of the Pottsville formation over the greater portion of the region covered by the westward-encroaching sea during Pottsville time, other and older beds of the Pottsville lie beneath it in the greatly thicker sections in the deeper portions of the trough to the eastward and southward, now represented in the Southern Anthracite field and the coal fields of the Southern States.

[b] The Sharon is often massive and resistant, as, for example, in its supposed representative, the Olean conglomerate, in the magnificent development at the Rock City, near Olean, N. Y. It is usually less thick than the Conoquenessing and less cemented or less durable than the Homewood sandstone. The Conoquenessing sandstone is usually the thickest, though generally a less massive member; the Homewood sandstone is usually massive, but often shaly, while varying from a few feet to 80 feet in thickness

COALS OF THE POTTSVILLE.

SHARON COAL.

The Sharon shale group varies from 0 to 70 feet, but in the western portion of the State usually has a thickness of about 40 feet. It includes one or more seams of coal, of which only the lowest, situated almost immediately above the Sharon conglomerate, is of any commercial importance. This, the Sharon coal, locally known as the "block" coal, was formerly the most important coal of the Pottsville in the main area of the bituminous coal field in this State. In Mercer County, to which its workable territory is chiefly confined, it consists of a clean, strong, fibrous coal, breaking in vertical joints, and remarkably free from sulphur. For many years it was highly valued by blacksmiths and was especially esteemed by ironmasters for the manufacture of pig iron, being used in a raw state in the furnaces. It is also highly appreciated for domestic fuel, for which it is still mined, though most of the areas of commercially workable thickness are now exhausted or nearly so. The commercial history of this coal dates from 1837. Its character as a fuel is described by Mr. Haseltine (p. 215) in connection with the discussion of the coal in Ohio, where the bed is much more extensively developed.

From its mode of occurrence the Sharon coal appears to have been formed in shallow swamps fringing the great Carboniferous basin. It is highly variable, thickening in the deeper portions of the little basins and often pinching out entirely near the margins. It enters the State in Mercer County, where it presents its Ohio characters and value. Here the principal developments of the bed are in Hickory Township, in which millions of tons of the coal have been taken from several basins, the seam measuring from 6 inches to 4 or 5 feet in thickness. In the eastern half of the county the coal thins and deteriorates, so that it is hardly of commercial value east of Mercer village. In the western townships it underlies only the more elevated portions of the county. In Lawrence County the bed is present, though lacking the "swamps" of pure coal found in Mercer County, while in Beaver County the bed is generally absent. The analysis of the fuel from the Williams mine, near the Lawrence County line, gives volatile hydrocarbon, 35.30; fixed carbon, 53.87; sulphur, 0.67; ash, 6.36; water, 3.790.

In the southern part of Crawford County the Sharon coal is found only in the tops of the knobs, where in most places it is below the standard of purity, though good at several points. The bed is nearly exhausted in East Fallowfield Township, where it sometimes furnishes 6 feet of good coal in the deeper portions of the little "swamps" or basins.

Along the northern boundary of the field the Sharon coal is generally traceable, though not of workable dimensions or quality. It is probable that the coal known as the "Quaker Hill" coal and locally worked for domestic purposes in Warren County belongs to this horizon. The Sharon coal is also correlated with the Upper Marsburg coal, which, with a thickness of 2 feet 4 inches or less, has been mined slightly in Lafayette Township, McKean County. It is not over 18 inches thick in the Gaines basin, Potter County, and it does not seem to have been recognized in the Ralston-McIntyre and Little Pine Creek basins of Lycoming County. Across the central portion of the coal field east of its main development in Mercer County the coal of the Sharon shale group is generally worthless if not absent. It is locally recognizable in the counties along the Allegheny front, but does not seem at any point to be of a thickness at present workable. In Fayette and Westmoreland counties the horizon of the Sharon coal is here and there represented by irregular lenses and wedges of coal, sometimes reaching a thickness of 3 feet. It is also found in shales and sandstones of the lower part of the Pottsville sections, and it is generally observed in most of the exposures on the Chestnut Ridge and Laurel Hill arches, extending across the southern tier of counties to the Potomac basin, where it appears to be known as the "railroad seam." In the Broadtop field the Sharon is supposed to be represented by a thin seam 1 foot 6 inches to 2 feet thick, about 125 to 140 below the Homewood near Powell station. It is possibly represented by the Mehoopany coal, 3 feet thick, in an area of about 300 acres near Forkston, in Wyoming County.

MERCER GROUP.

The second horizon of commercially valuable coal in the Pottsville formation is embraced by the Mercer group, lying between the Conoquenessing and Homewood sandstones. This group has a thickness varying from 15 to 60 feet, and consists of a highly variable series of beds, which in the northwest corner of the area are composed of about 52 feet of dark shales, including fire clays and two coals, the lower Mercer and the upper Mercer, each locally overlain by a limestone, with the occasional addition of an iron ore. Along the northern margin of the field the limestones disappear to the eastward and 3 or 4 irregular coals with local developments of refractory fire clays appear in the dark shales. In the eastern counties of the field these are replaced by gray shales, thin sand rocks, and most important refractory clays, including the celebrated Mount Savage fire clay.

The coals, which are seldom of any economic value, are generally patchy, irregular, or lenticular; hence it is impracticable to attempt to identify the coal of a single horizon in distant parts of the basin. The coal beds usually contain much dirt or sulphur, though at many localities they offer an excellent fuel, of great purity and utility. In the northeastern area the most valuable fuel of the region is obtained from this group.

About the type locality in Mercer County, the two Mercer coals are hardly of commercial importance, though both are locally workable, with a thickness of 4 to 7 feet of highly impure coal. In Wilmington the upper coal is worked in two benches, each 2 feet thick, with a 10-inch parting of fire clay. In the southeast corner of the same township it is in two benches of 2 feet 6 inches each, with 3 feet of shale parting. It measures 3 to 4 feet in Lake Township and 2 feet 6 inches near Sandy Lake. In Sandy Lake Township a coal, perhaps representing the Lower Mercer, was worked by the Maple Grove Company in two benches, 4 feet and 1 foot 6 inches, separated by 4 feet of fire clay. The Lower Mercer coal, which at a number of points resembles the Sharon block coal in structure, is generally more persistent in this district, though almost invariably high in sulphur and ash.

In Lawrence County this bed is locally a block and cannel coal. In this district both Mercer coals are generally dirty and of no commercial value, though they measure 3 feet 4 inches in portions of the area and even reach a thickness of 5 feet west of Edenburg. In Butler County the beds are thin and worthless and often represented by bituminous shales only. In Allegheny, Washington, and Greene counties the group is concealed, but the drill has not indicated any beds of the least importance at this horizon west of Chestnut Ridge, in southwestern Pennsylvania.

East of the Allegheny River the Mercer group improves somewhat in respect both to the thickness and the value of its coals, although the degree of exploitation is due generally to advantage of position rather than to the intrinsic merit of the fuel. In Clarion County the coal of this group has been worked to some extent on Catfish Run and at North Pine Grove, and although the bed is extremely irregular it is locally free from sulphur. At other points in the county it contains small areas of clean, bright coal about 3 feet in thickness. In Venango County the Mercer group has little extent and no value, and in Warren County the area is small and of no more than local importance. In Jefferson County the two coals of the group are here and there in better condition, while a third coal is opened locally for country use. A coal correlated with the Upper Mercer is in good condition in a belt along the central portion of the county. It has been somewhat extensively exploited on a commercial scale near Fullers and Iowa Mills, where it has a thickness of 3 to 5 feet. It is very irregular and rolly, and contains considerable earthy matter. It has also been mined at Port Barnet, and it shows 5 feet of coal at Camp Run. In Winslow township the Lower Mercer coal, which is close to the Upper Mercer over much of the county, is 2 feet 6 inches thick locally.

Still farther south, in Armstrong County, the Mercer group carries thin beds of coal 1 to 2 feet thick, of good quality in places, but mere streaks at other points, while in Indiana County the coals are of no value.

The Mercer group is the principal source of coal in McKean County, where three horizons are workable, though not more than one horizon is productive at any single locality. These horizons are locally known as the Upper, Middle, and Lower Alton coals. The Upper Alton has a thickness of 2 feet in the Alton basin, in Fayette Township; 2 feet to 3 feet 6 inches in the Clermont basin, where it is still worked for shipment on Fourmile Run; and 2 feet to 3 feet 6 inches at Buttsville, where it was formerly worked. The Middle Alton coal, 5 to 12 feet below the Upper coal, is thickest at Alton, and has been worked there in a section showing a thickness of 4 to 8 feet in two to four benches. It here contains 1 to 3 per cent of sulphur and 8 to 16 per cent of ash. The Lower Alton coal has an average thickness of 4 feet in the Norwich basin. It shows 2 feet 6 inches to 4 feet in two benches, separated by 2 to 8 inches of shale near Clermont.

In Elk County, at St. Marys, the Upper Alton coal is 2 feet 7 inches thick and too poor to work; north of Benezette it is 2 feet 8 inches to 4 feet; in Fox Township it is 2 feet 11 inches to 4 feet 2 inches, with three partings, and impure, and near Irwins Mill 4 feet 5 inches. It is but little worked on account of its sporadic and unreliable nature. The Middle Alton coal has a thickness of 2 to 4 feet near Benezette, of 3 feet 10 inches on Spring Run, where it contains 2 per cent of sulphur and 4.670 ash, and of 3 feet 6 inches at Weedville, where it furnished clean, bright coal under 6 inches of poor coal and where it was formerly mined. The Lower Alton coal is 3 feet thick, but of little value, at St. Marys; it is 2 feet 11 inches thick in Fox Township, and 3 feet 2 inches in thickness near Irwins Mill. It is generally too dirty for exploitation under present market conditions. In the northwestern portion of the county neither the Upper coal, 3 feet thick, nor the Lower, 4 feet thick, appears to be of any definite commercial value.

A bed, with a thickness of 3 feet 8 inches, supposed to represent the Upper Alton, was formerly mined to some extent on Sterling Run and at the Mount Hope mines in Cameron County, and a bed probably at the same horizon shows 4 feet of coal at a number of points in Clinton County, though in both these counties it appears to be too sulphurous to mine on a commercial scale. It is said to be the bed mined on Beech Creek, near Cato, Center County, though only 8 inches of coal is shown in the Moshannon tunnel near the western border of this county.

On the Susquehanna River and on Clearfield Creek, in Clearfield County, a coal 1 foot 6 inches to 2 feet 6 inches in thickness is locally observed in the Mercer group. This coal is generally not workable except in the southern and eastern portions of the county, where it is occasionally mined in connection with the exploitation of the Mount Savage fire clay. In this region the coal sometimes attains a thickness of 3 feet, and is worked in the vicinity of Sandy Ridge and on Bear Run. At Wopsononock, in Blair County, the extensive stripping has well displayed the variable thickness of this coal, which is of poor quality. One or more beds are present at this horizon at Bennington, South Fork, and along the viaduct axis in Cambria County. The Mercer group is well exposed below the Ingleside mines, south of Johnstown, and at the old clay banks near Keystone, as well as in the Pennsylvania portion of the Potomac basin, where the coal occurs in company with the Mount Savage fire clays, and is known as the "Mount Savage coal." The coal ranges from 4 inches to 4 feet, usually 2 feet to 3 feet over large areas, and is mined at most of the clay mines for burning the fire clay, while at the Hoblitzell mine it is worked on a very small scale for shipment also. At a number of points in Somerset, Cambria, and Clearfield counties this coal, which in most cases is impure or highly sulphurous, has generally been erroneously referred to the Brookville horizon.

In the Broadtop field the Mount Savage coal has been mined to some extent in Bedford County, although in Huntingdon County it thins to less than 2 feet in the main Broadtop basin, and is said to range from 1 to 2 feet near Robertsdale in the east Broadtop basin.

The importance of the Mercer coals in the northeastern portion of the Great Appalachian basin is further shown by the extensive mining operations in the outlying areas in Potter, Lycoming, and Bradford counties. In these counties they represent the most important coal-bearing horizon; for it is to this horizon that the Gaines coal of Potter County, the celebrated Bloss coal of Tioga County, the "B" coal of the Ralston and McIntyre basins of Lycoming County, and the "B" coal of the Barclay basin in Bradford County belong, although these beds are generally regarded as representing the Lower Kittanning coal, on which account they will be treated with the latter in this report.

The Bear Run coal, about 20 feet below the Bloss coal, 2 feet thick near Blossburg and 2 to 3 feet near Arnot, in the Blossburg basin, appears to lie in the lower portion of the Mercer group, to which also the "A" coal of the Bernice (semianthracite) basin seems to belong.[a] Analyses of the Mercer group coals are given in the table on page 183.

ALLEGHENY FORMATION (XIII).

GENERAL CHARACTERS AND THICKNESS OF THE FORMATION.

Nearly 40 per cent of the bituminous coal mined in Pennsylvania is derived from the Allegheny formation. This formation embraces the surface rocks which cover the greater part of the Allegheny Plateau,

[a] The Dunmore No. 3 and the red ash coals at Forest City, in the northern anthracite field of Pennsylvania, probably belong to the same group and horizon.

and is exposed for a great distance along the Allegheny River in the western part of the State, as well as in belts of varying width along the major anticlines. It consists of shales, sandstones, coals, more or less irregular thin limestones, and local thin developments of iron ore. It contrasts strongly with the distinctly arenaceous Pottsville formation beneath it by its relatively soft composition, by its large proportion of coals, and by the increased percentage of limestone. Its carbonaceous character helps to distinguish the Allegheny from the overlying Conemaugh formation, or Lower Barren measures, which contains in general but few locally workable coals and whose distinctly arenaceous, often conglomeratic base, immediately superimposed upon the Allegheny series, is, in a broad way, succeeded by more numerous and fickle limestones, and in certain areas by large bodies of red and green shales.

The thickness of the Allegheny formation varies greatly in different parts of the State. Along the Allegheny River and in the western counties it has a reported range of from 275 to 350 feet. In Jefferson and Clarion counties it averages from 300 to 335 feet. Along the Allegheny escarpment it decreases to a thickness of from 200 to 250 feet to the northward, although it thickens somewhat locally to the southwestward. In northern Somerset County, however, it is said not to exceed 250 feet, and this thickness obtains in general through a belt extending slightly north of west to the Allegheny River, although the formation thickens again to the southward to 300 feet in Washington County and to about the same near the Maryland line in the Potomac basin in southern Somerset County. Contrary to the general rule of increase in thickness in passing eastward, the reported measurement of the Allegheny formation in Huntingdon County is but 200 feet, and in the Blossburg basin, Tioga County, 150 to 160 feet. The average thickness of the formation throughout the entire bituminous regions is approximately 275 feet.

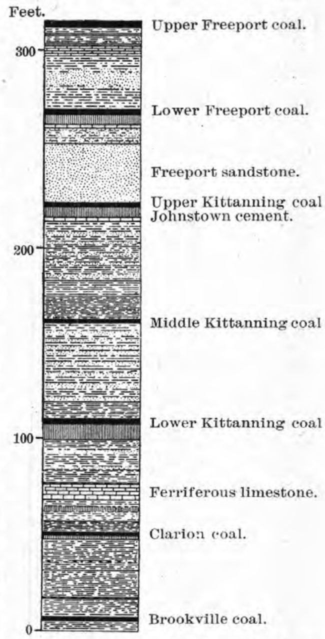


FIG. 22.—Section of the Allegheny formation on Allegheny River, Armstrong County.

The typical composition and sequence of the terranes in the Allegheny formation, with the average thickness of the members, is shown in the general section given in fig. 22. It will, however, be understood that, as in other formations and other regions, the coals of the Allegheny series are more or less irregular and variable, both as to composition and extent. The coal at a given horizon may be sometimes several feet thicker at one locality than at another one less than a score of miles distant, or it may be a steam coal in one locality and a so-called cannel in another.

The key rocks used in identifying the coals of the Allegheny formation are (1) the Homewood sandstone, the topmost member of the Pottsville formation, which lies but a few feet below the lowest coal of the Allegheny formation; (2) the Ferriferous limestone; (3) the Johnstown cement bed; (4) the Lower Freeport limestone; (5) the Mahoning sandstone, which constitutes the basal member of the Conemaugh formation. The stratigraphic identification of the coals is based for the most part on their relative position with reference to one or more of these key rocks, and to one another. Of the key rocks the most persistent are the Homewood sandstone at the base of the formation, and the Mahoning sandstone at the top of the Allegheny. The Ferriferous limestone, which lies a short distance below the Lower Kittanning coal, is a variable bed, seldom recognized east of the Chestnut Ridge anticline, while even in the western half of the coal fields it is remarkably fickle, often disappearing entirely within a distance of a few miles. It is most reliable as we approach the Ohio boundary, along which, in Beaver County, it sometimes reaches a maximum thickness of over 30 feet. Similarly the Johnstown cement is rarely distinguishable in the western half of the coal field, it being seldom found in the same sections with the Ferriferous limestone. It becomes more persistent and reliable, especially in the southeastern counties, as we approach the Allegheny escarpment. It is from 0 inches to 4 feet in thickness in Clearfield County, locally 5 feet thick in Cambria County, and in Somerset County it reaches a thickness of from 6 to 8 feet. In Westmoreland County it is said to be always uncertain and confined chiefly to the northern portion. In those sections in which both the Ferriferous limestone and the Johnstown cement are absent the Lower Freeport limestone, which is nearly always present where the other two are wanting, is used, although this too is locally absent in various parts of the coal basins, especially in the small areas to the eastward.

COALS OF THE ALLEGHENY.

The commercial bituminous output of the Allegheny formation is derived almost exclusively from seven horizons or coal beds which, in ascending order, are generally designated as the Brookville (A), Clarion (A′), Lower Kittanning (B), Middle Kittanning (C), Upper Kittanning (C′), Lower Freeport (D), and the Upper Freeport (E). The general stratigraphic relation of these coals is illustrated in the generalized Allegheny section on page 137. For convenience of description these coals are often separated into three groups: (1) the lower or Clarion group, embracing the Brookville and Clarion coals, lies between the Homewood sandstone and the Ferriferous limestone; (2) the Kittanning coals, which fall within a thin series of more or less distinctly argillaceous beds, are treated as a group, lying between the Ferriferous limestone and the Lower Freeport sandstone; (3) the Freeport coals constitute the third group, which terminates at the roof of the Upper Freeport coal.

BROOKVILLE COAL (A).

The Brookville coal, the lowest coal of the Allegheny formation, lies almost immediately above the Homewood sandstone, the interval being from 3 to 15 feet. Owing to the protective support of the underlying Pottsville its exposure zone is exceedingly broad, extending in a wide belt far out on the fringe to the northward. It takes its name from the county seat of Jefferson County, in the northern part of the main field. It extends in workable thickness over the greater part of Jefferson County and has been mined for local use at a large number of points, especially about Brookville. Here it is found in its best condition, although in general the coal is too shaly and too sulphurous for present commercial exploitation, especially in view of the competition of the unusually valuable fuels of the Reynoldsville basin in the same county. It is the principal coal of the northwestern half of the county.

The coal at the Brookville horizon is highly variable in thickness in Indiana County, ranging from 18 inches to 4 feet. It is used here and there locally, especially in the brick kilns, although the proportion of pyrites renders it unfit for marketing. In passing southward through Armstrong County it decreases from an average of 18 or 20 inches in the north to a thin and worthless bed in the lower part of the county. Over most of Clarion County this coal is either worthless or unrecognized, though it improves in character and is available for local use in the eastern townships. It is reported to be thin and often absent in Lawrence County and southern Butler County. In northern Butler County it varies from 6 inches to 5 feet in thickness and is locally mined, especially in the northern townships. Even here it forms an inferior fuel, on account of the numerous sulphur bands which it contains. In Beaver County the Brookville coal is said to be thin and of no commercial value, its thickest exposure—3 feet—being very shaly. Along the Ohio River it is represented only by bituminous shale at many points. It is possible that the Pardoe coal, which is mined to some extent on a commercial scale in northwestern Butler and southeastern Mercer counties, belongs in reality to the Brookville horizon, as some geologists believe, although it is generally referred to the Clarion horizon. A similar condition exists in several of the northeastern counties, namely, Elk, Forest, McKean, and Cameron, where the coal is seldom represented and would seem to be absent unless it is identical with the Clermont coal, which has been correlated with the Clarion. However, in Clearfield, Center, and the counties to the southward, the Brookville horizon is almost everywhere recognized.

In Clearfield County this coal occurs about 70 feet below the Lower Kittanning coal. It is very irregular, varying from a few inches to 4 feet in thickness, very dirty and sulphurous when of workable dimensions, and usually very thin when of good quality. In Center County, however, the bed is in better condition, locally measuring 4 feet, though it does not appear to average over 3 feet in thickness and is generally rather impure. Nevertheless, the Brookville is an important horizon in this county, in which it underlies a large territory that has as yet been very little prospected.

Tests of the areas of this bed along Beech Creek are very favorable, indicating a thickness of nearly 4½ feet, including a 4 to 6 inch parting 7 inches from the top. Analyses of the fuel in this vicinity show the presence of 0.83 per cent sulphur and 15.31 per cent ash. Along Moshannon Creek, in the western margin of the county, the coal occasionally exhibits a section 4 to 4½ feet in thickness and has been worked to some extent, although it is generally too dirty and sulphurous for the market, especially as it has to compete with the superior coals of the Philipsburg-Houtzdale basin. On the whole, however, the thickness of the coal of this horizon in Center County and its favorable situation with regard to the market bespeak more careful prospecting and probable exploitation when the richer fuels of the higher group in the basin to the westward are exhausted.

The Brookville coal ranges from 2 feet 4 inches to 6 feet in thickness along the Allegheny escarpment in Cambria County, and along the western margin of Blair County, where it has been commercially mined to some extent at several points, though at most places, including Bennington, it has been abandoned on account of the large percentage of sulphur. At Bennington it reaches a thickness of 5 feet. It has been somewhat extensively worked at the Glen White mine, where it shows 2 feet 3 inches of coal under 8 inches of bone. Near Johnstown the seam has a thickness of 6 feet 10 inches, with an upper bench of 4 feet 6 inches and a lower bench of 1 foot 10 inches, separated by 6 inches of shale; but only 3 feet 6 inches of the Johnstown section is of value, and even this is more or less shaly and contains a large proportion of sulphur, which unfits it for other than domestic purposes.

In Somerset County the coal frequently attains a thickness of 4 feet, and is said to reach 6 feet, but it appears to have little value on account of the large amount of sulphur. However, it is mined to some extent from a bed which has a thickness of 3 feet 6 inches along Castleman River, and on the flank of Negro Mountain. It is probable that the coal which has been described in connection with the highly refractory fire clays as belonging to the Brookville horizon along or near the Allegheny escarpment, in Somerset, Cambria, Center, and Clearfield counties, belongs in reality to the Mercer group of the Pottsville formation, and that the Brookville is represented by a higher and perhaps a better coal, which has locally been erroneously referred to the Kittanning group. The Brookville coal is generally of no value in that portion of Ligonier basin which lies in Fayette County, though it is said to be of good quality and locally of workable thickness on the western slope of Chestnut Ridge in Westmoreland County.

It is probable that the Cook or Fulton coal, of the northern portion of Broadtop basin, in Huntingdon County, is also referable to the Brookville horizon. In the Broadtop field this coal has been opened and is still being mined to a slight extent near the western margin of the field, with an average thickness of from 2½ to 3½ feet, and the coal is said to have once been coked to some extent in the vicinity of Powelton. It is best on Shoup's Run, where it sometimes increases to 6 feet 6 inches, while at one point it shows a thickness of 8 feet 8 inches, though it is here badly damaged by sulphur and partings. In the eastern portion of the Broadtop basin the coal is hardly of sufficient thickness and purity to work in competition with the Barnet and Twin seams, although it will doubtless, at some time in the future, furnish a source of fuel, especially in the small areas along the Rocky Ridge basin, where, at the Schliemann coal bank, it exhibits a section of 4 feet 6 inches to 5 feet (upper bench) and a lower bench of 1 foot 6 inches, showing less than 1 per cent of sulphur.

If the Bloss coal of Tioga County is referable to the Mercer group, as appears from certain evidence to be the case, the Cushing or Seymour coal should probably be referred to the Brookville horizon. This coal, which was formerly worked about Blossburg, Morris Run, and Arnot, and which is now commercially worked to some extent in the Antrim slope, shows at Arnot a thickness of 2 feet 8 inches and contains 0.907 per cent of sulphur and 4.753 per cent of ash. At Antrim the coal reaches a thickness of 5 feet 6 inches, but in portions of the mine it is said to contain 2.8 per cent of sulphur. The Bear Run bed of the Blossburg basin, which was correlated by the State geologist with the Brookville coal, but which appears to the writer to belong to the Pottsville formation, is about 1½ feet in thickness, though locally showing from 2 to 3 feet in the vicinity of Blossburg and 2 feet in fair quality near Antrim.

On the whole, it would appear that the Brookville coal is of workable thickness locally over a large part of the marginal belt of the coal fields, and that to some extent it has been worked commercially on account of its nearness to the markets, although it is nearly always too impure to compete with the superior coals lying not far distant within the field. The ultimate exhaustion of the Kittanning and Freeport coals will, perhaps, lead to an extensive development of the Brookville in Jefferson, Clearfield, Center, Cambria, and Somerset counties, of which Center and Clearfield afford the strongest geographical advantage combined with a fair thickness and a locally relatively pure condition.

CLARION COAL. (A^1)

The Clarion horizon is the second broadly extended coal-bearing horizon above the base of the Allegheny formation. It lies normally from 10 to 70 feet below the Ferriferous limestone and about 35 feet above the Brookville coal. Like the latter, it has a very broad zone of exposure along the northern side of the field and along the anticlinal axes in the interior of the main Coal Measures area.

The Clarion coal resembles the Brookville coal in that it is in general best and thickest toward the outer or shoreward border of its exposure zone, the more central sections being, with some exceptions, thinner, and even obscure. In its mode of occurrence, with relation to that of the Brookville coal, the Clarion illustrates a condition commonly prevailing in the coal groups of the Allegheny formation, i. e., the failure of two approximate coals to be of workable thickness in the same locality.[a] Thus the Clarion coal is extremely rare of workable thickness in a section containing a workable thickness of coal at the Brookville horizon also.

The Clarion coal is typically exposed and locally mined about Clarion, in Clarion County, in a section showing about 4 feet of impure and somewhat sulphurous coal. Over the greater part of the southern half of the county it is thin and worthless, though it shows 2 feet 6 inches at Fairmount on Redbank Creek and along the northern border of Armstrong County, where it has been somewhat extensively mined for steam purposes. Toward the western boundary of Clarion County it improves, and in the northwestern corner of Armstrong County it averages from 2 feet to 2 feet 6 inches in thickness, and, though sulphurous, it is the chief source of fuel about Parker, where a thickness of 3 feet 6 inches, with a 1-inch parting, is disclosed.

In Jefferson County this coal is usually very thin, often but a few inches in thickness, and very impure where it is thicker. In Indiana County, also, the bed is thin and unimportant, though fairly persistent. The general condition noted in western Clarion and northwestern Armstrong counties extends to the counties to the westward also. It is the main coal in the thin residual sections capping the knobs in Venango County, where it has been used by the oil drillers, though the fuel is too restricted in area and too impure for the general commercial market. In northern Butler County the Clarion is of workable thickness, and is locally less impure. It is said to be mined 3 feet

[a] An exception to this rule is seen in the local workability of the Upper Freeport over the Lower Freeport coal in the Houtzdale region of Clearfield County.

6 inches thick near Parker, and 7 feet thick at Martinsburg. Here it is in two 3-foot benches, with a 1-foot parting. Southwestward the parting disappears for the most part, but to the northward it thickens to 7 feet, making the whole bed about 14 feet thick. Still farther northward the coal expands by the introduction of thick partings so as to cover an interval of over 25 feet near Edenburg, in northern Clarion County.

In northwestern Butler County and in eastern Mercer the Clarion coal, or its supposed representative, the Pardoe coal, is mostly of workable thickness, and constitutes the main coal of the Allegheny formation in that district. In Mercer County the Pardoe coal is reported in twenty-one isolated areas on the knobs and high divides in the southern and eastern portions of the county, where it averages from 2 to 3 feet in thickness. In Jackson and Lake townships it is mined somewhat extensively, although it is variable both in character and composition and very irregular, the outcrop showing from 6 inches to 5 feet of coal, which is usually cut up by one or more partings, and at best can not be depended upon for more than 2 feet 6 inches of good coal. In Lake Township the bed increases to 4 feet 9 inches in thickness, with a sulphurous parting near the middle. A number of mines are operating in this coal at Pardoe and Grove City in Mercer County and along the Pittsburg, Bessemer and Lake Erie Railroad in northern Butler County.

On the whole, chiefly on account of the rather high percentage of sulphur, the Clarion coal in this part of the State is not generally good, though its easy accessibility and geographic advantage have led to its somewhat extensive exploitation. The fuel is principally utilized in locomotives in northwestern Pennsylvania and Canada.

In Lawrence County both beds of the Clarion are mined at Eastbrook, where they lie close together, but over most of the county the coal is said to be thin and of no present commercial value. Farther south, in Butler County, it seldom reaches 1 foot 6 inches in thickness, while in the counties to the southeast it is worthless or unrecognized until the Ligonier basin is reached, where, in southern Fayette, it is reported as from 3 feet 6 inches to 5 feet 5 inches thick, though impure and badly split by partings. In Cambria and Somerset counties the Clarion coal is said to be of little or no value, but it appears probable that in southern Somerset County the Clarion horizon has at some points been incorrectly determined.

In the counties northeast of Jefferson County the Clarion group contains only one coal-bearing horizon, that of the Clermont coal, and this, although often in the position of the Brookville coal, near the top of the Homewood sandstone, has generally, on account of its relation to the Ferriferous limestone, 80 feet above, been correlated with the Clarion coal, the Brookville coal being regarded by the State geologist as absent in this region. The Clermont coal takes its name from Clermont, in McKean County, and is the most important coal of the Clermont basin in this county. About the type locality, where it is now nearly exhausted, it measures 3 feet in thickness, although it is variable. In the Fifth basin it ranges from 2 feet 3 inches to 4 feet in thickness, averaging 2 feet 11 inches, and has been mined to some extent. It is reported as yielding 40 per cent of volatile combustible matter at some points, but the seam is sulphurous and contains a thin parting.

In the Alton basin, Lafayette Township, the Clermont bed reaches a thickness of from 3½ to 5 feet, though the coal is so impure as to be of little commercial value. It is also reported in the Potato Creek basin, in the southeastern part of the county, where it has been worked to a very small extent. In this county the Clermont coal has generally but little cover and is suitable for steam and domestic purposes only. In the southeastern part of Elk County this bed is reported with a thickness of 4 feet 6 inches, and in the Caledonia basin, Jay Township, it attains a thickness of 5 feet 6 inches. The Clarion and the Alton coals afford the best fuel in the eastern part of this county. On Toby Creek, near the southern boundary of the county, however, the Clermont coal shows a thickness of 2½ to 3 feet, and was formerly mined to some extent near Brockport, but is not mined now largely on account of the presence of the better coals of the Dagus and Lower Freeport horizons in the same district.

In Cameron County the Clermont has been worked to some extent in the Cameron basin southeast of Emporium, where at the Mount Hope mine it exhibits a thickness of 4 feet, without bone but with considerable sulphur. On Canoe Run this coal has a thickness of 3 feet 4 inches. A coal supposed to be the Clermont coal occurs in the tops of a large number of knobs, including many thousands of acres, in the first and second bituminous basins in Clinton County. In portions of the Renovo (second) basin it measures 3½ feet in thickness, but yields over 1 per cent of sulphur and 19 per cent of ash. In Center County the Clarion, which is present at from 15 to 25 feet above the Brookville coal, is thin and worthless, measuring from 1½ to 2 feet.

The Scrubgrass coal of western Clarion, Venango, and northern Butler counties has been correlated by the State geologist with the upper bench of the Clarion coal, and is now often designated as the Upper Clarion coal. It occurs generally close beneath the Ferriferous limestone, and although traceable over a relatively large area it is rarely of workable thickness, although in some places, as in western Clarion County, it is of good quality. In the extreme northwest of Armstrong County it measures 2½ to 3½ feet in thickness, but is somewhat shaly and pyritous. In Mercer County it appears to be only 1 foot in thickness and of no value. The coal, about 3 feet thick, mined near Wilmington, in northern Butler County, is said to represent the Scrubgrass coal, although the latter is reported as unworkable in other portions of the county, while its horizon is not distinguishable to the southwestward.

Analyses of this coal, which appears in general to be suited only to domestic and railroad use, are given in the table on page 183.

LOWER KITTANNING COAL (B).

The Lower Kittanning is the most persistent, uniform, and reliable coal of the Allegheny formation, although it is thinner than the Freeport coals, seldom exceeding a workable thickness of 4 feet. Its purity, regularity, and extended accessibility make it first in production among the coals of the formation. The zone within which it lies less than 300 feet below the surface includes nearly one-half of the entire area of the main coal field. In 11 of the counties it is exposed in workable thickness and purity. Although locally it is thin or worthless, its commercial output in the State is probably over 25,000,000 tons annually, while the number of commercial mines and country banks at this horizon is greater than in any other coal in the field except the Pittsburg.

In the Allegheny Valley the Lower Kittanning coal lies about 45 feet above the Ferriferous limestone, and 180 to 200 below the Mahoning sandstone. In Clearfield County, near the Allegheny escarpment, it is about 145 to 165 feet below the Mahoning sandstone. Like the coals of the Clarion group it is, on the whole, thickest near the outer margin of the zone of outcrop. In the western part of the State its quality is not so good as to the eastward and along the Allegheny front.

The bed takes its name from Kittanning on the Allegheny River in Armstrong County, where it is mined to burn the plastic fire clay which occurs a few feet below the horizon of the coal. It is regular and fairly persistent in this county, though thin and more or less impure toward the south, where it seldom exceeds 2 feet in thickness. It is seen in its best condition along the Allegheny Valley at the mines in the neighborhood of Redbank, where it has been worked with a thickness of 4 feet. Nearly always it carries a thin, bony top, and usually a thin parting. In the western area this coal is ordinarily pyritous, and more or less shaly when thick, and purer when thinner. It is commercially mined at the Riverview mine below Reimerton, though the proportion of sulphur unfits it for other than steam and grate use.

In Jefferson County, where the Lower Kittanning coal has been well prospected for burning the Ferriferous limestone on the farms, the coal is regular and persistent, though generally thick and often poor in quality. It has been worked in a number of small banks near the western border of the county. Toward the east it improves somewhat, and occasionally shows a thickness of 4 feet in the undeveloped regions of the northern and eastern portions of the county, where its exploitation has been discouraged by the predominance of the magnificent Lower Freeport coal in the Reynoldsville basin. The Lower Kittanning coal in the latter region is a dry, firm, and fairly pure coal. Next to the Lower Freeport coal, the fuel of this bed is the best that has been found in Jefferson County.

In Indiana County the Lower Kittanning lies 50 to 100 feet above the Homewood sandstone and exhibits an average thickness of about 2 feet 6 inches of coal, generally split by a thin shale band. It improves somewhat to the eastward, showing 2 feet 9 inches in thickness, with a 1-inch parting 10 inches from the base. At a number of points it reaches a thickness of 5 feet, and at one locality a measurement of 7 feet 2 inches is reported, but in its thicker sections the seam is generally bony and quite impure.

This coal is accessible over most of Clarion County, with the exception of three townships in the northern portion. In the northern half of the county it averages about 2 feet 8 inches in thickness, and in the central portion from 3 feet 3 inches to 4 feet 6 inches. Generally it carries one or two very thin partings. It is worked at a number of points in the southern part of the county along Redbank Creek, where thicknesses as great as 4 feet 11 inches are reported. On Sligo branch of the Allegheny Valley Railroad it is the seat of a number of commercial mines, and it is valuable as a steam coal, although it usually carries nearly 2 per cent of sulphur. The reports indicate a workable thickness for this seam over a large territory in which, on account of lack of adequate transportation facilities, the coal is undeveloped. Nine analyses show volatile hydrocarbons 35.695 to 41.575 per cent, ash 2.265 to 8.160 per cent, and sulphur 0.818 to 3.789 per cent.

In Center County, on the eastern edge of the main bituminous coal field the Lower Kittanning coal, although slightly inferior in quality to the Upper Kittanning coal, has, since the partial exhaustion of the latter, been very extensively developed, particularly in the Snowshoe basin. In this basin it typically occurs in two benches of 6 inches to 3 feet 6 inches and 2 feet 10 inches to 3 feet 1 inch in thickness, separated by a parting 2 inches to 6 inches thick. In this district the seam furnishes a large output, a portion of which, after careful cleaning, is coked by the Lehigh Valley Coal Company. Eastward from Snowshoe a considerable area of undeveloped territory, carrying 4 feet of good coal in two bands separated by 4 to 6 inches of bone, is reported in the knobs along Beach Creek. A coal probably belonging to this horizon has been developed to some extent with a locally reported thickness of 4 feet in the vicinity of Karthaus, in the Renovo basin, at the northwestern boundary of the county.

In the Philipsburg-Osceola basin, along the western margin of Center County, the Lower Kittanning coal has been mined to a great extent near Osceola and at Powelton, where it yields from 2 to 6 feet of coal with two partings, the top 8 inches of coal being usually slightly bony and a little high in sulphur, which, however, occurs in an aggregated form and is removed without difficulty. The seam appears to be more sulphurous southwest of Osceola, though it is here neglected for the higher and thicker beds.

In Clearfield County the Lower Kittanning coal varies from 3 feet to 7 feet in thickness, having an average of 4 feet. In the Philipsburg-Houtzdale basin it contains a 6-inch shale parting and is very little worked where the Lower Freeport coal is present. In the southern part of the county, however, the seam is in fine condition, at many points furnishing 4 feet 9 inches of commercial coal, sandwiched with two thin partings. Analyses show 72 per cent fixed carbon, 21 per cent volatile matter, and 5 per cent of ash.

Along Moshannon Creek the seam contains about 0.627 per cent of sulphur and 7.125 per cent of ash. At Davis Bank, where it is worked, a section of the bed shows coal, 1 foot 8 inches; bone, 4 inches to 8 inches; coal, 3 feet 4 inches; shale, 1 foot to 1 foot 6 inches; coal, 1 foot. On Moravian Run, in the same county, the coal exhibits an exceptionally fine section, measuring 8 feet, with but 6 inches of parting.

The exhaustive exploitation of the Lower Freeport coal in Clearfield County is destined to bring about the development of large areas of the Lower Kittanning, which is accessible over a greater part of the area.

In Cambria County the Lower Kittanning coal is locally known as the Miller seam or Sonman coal. In this part of the State it has been in recent years the seat of an enormous development, even overshadowing the exploitation of the Freeport group, and, near the southern border of the county, furnishing the output for one of the largest bituminous coal mines of the State. Along the eastern border of the Cambria region the Lower Kittanning horizon is well proved and has an established reputation, especially for steam and smithing coal. Locally, also, it yields in some areas a most excellent coke. The fuel is low in sulphur and generally high in fixed carbon. About Southfork and Johnstown it contains about 18 to 20 per cent of volatile matter. At Bennington, just to the east of the Allegheny crest, the seam measures 3 feet 6 inches to 4 feet with a parting which leaves 3 feet 8 inches to 3 feet 10 inches of clean coal. This coal, which is still worked at a number of mines in this vicinity, is said to yield 28 per cent volatile hydrocarbon at Bennington, where at one time it was coked to some extent. The bed is mined farther north on the east slope of the escarpment, where it is double, the upper bench, the only one mined, showing 2 feet 7 inches of clean coal topped by 6 inches of bony coal. This bench yields 0.978 per cent of sulphur and 8.510 per cent of ash, with about 30 per cent of volatile hydrocarbon. At the Baker mines, in Blair County, it yields but 5.6 per cent of ash. The lower bench, 2 feet 3 inches to 3 feet thick, beneath 1 inch to 1 foot 3 inches of fire-clay parting, contains about 4 per cent of sulphur and 17 per cent of ash.

At several points near Lloydville, in the extreme northeastern corner of the county, the Lower Kittanning shows 8 feet 6 inches of coal in three benches, including 5 feet of good coal, but the fuel is not so good as that in the southern part of the district. The entire seam, which, near the Clearfield line, averages about 4 feet in thickness, including the top bone and the partings, is higher in both ash and sulphur than in the central and southern portions of the State, and it is even better in the Wilmore or First basin than in the Johnstown or Second basin, where the product is somewhat sulphury, although locally yielding 3 feet 4 inches to 4 feet of clean coal. Analyses of the fuel mined about Sonman, to the southwest in the Wilmore basin, where it is known as the "Miller" bed, do not show over 5 per cent of sulphur or 6 per cent of ash. The coal is also worked on the western side of the first bituminous basin in Cambria County, in the valley of the Susquehanna River. There it yields 3 feet 2 inches of coal, capped by 6 inches of bone and an upper 8-inch bench of coal. In the vicinity of Southfork the Kittanning coal is mined almost exclusively with a thickness of from 2 feet 6 inches to 5 feet, an average analysis showing 16.48 per cent of volatile matter, and 0.774 per cent of sulphur.

In the northwestern part of the county the Blacklick bed, which is supposed to lie at the Lower Kittanning horizon, appears to be regular over a considerable area and shows an upper bench of 3 feet 1 inch to 4 feet 3 inches, averaging about 4 feet in thickness, with a middle bench averaging 4 inches, and a lower bench 6½ inches to 2 feet 1 inch, averaging 1 foot 1 inch in thickness. The lower bench is impure, but the upper yields 70 to 74 per cent of fixed carbon, 20 per cent volatile matter, and 1 to 8 per cent of sulphur, with about 6 per cent of ash.

The developments in the basin of the South Fork of the Conemaugh River, in southern Cambria County, within recent years, have given the Miller or Lower Kittanning coal its supremacy as the chief coal of Cambria County. Although it is somewhat irregular and locally rolling, varying, when in good condition, from 3 to 5 feet, it averages well, a typical section revealing bone, 0 inch to 2 inches; coal mining bench, 3 feet 6 inches to 3 feet 8 inches; shale and bone, 4 inches; bottom coal, impure, 1 foot to 1 foot 4 inches. An average analysis in the central portion of the basin shows 76.46 per cent of fixed carbon and 0.714 per cent of sulphur.

The southward extension into northern Somerset County of the fine development of the Lower Kittanning coal has led, within a few years, to the establishment, near Paint Creek, of one of the largest mines of the State. In the latter county the Lower Kittanning is, next to the Pittsburg coal, the most important coal-bearing horizon. In the northern part of the county, where it is particularly valuable, it is a double bed with a thick upper mining bench of pure, lustrous, columnar coal, 3 feet to 5 feet 2 inches in thickness, separated from a thinner impure lower bench by a thick parting of bone and shale, 5 inches to 10 inches in thickness. The lower bench, 1 foot 6 inches in thickness, is usually left. The upper bench carries from 2 inches to 4 inches of bone at the top. Thirty-three sections of the mining bench in this district show an average of 3 feet 10 inches of good coal. Sixty analyses give sulphur 0.880 per cent and ash 6.108 per cent.

This coal, which on analysis appears to be nearly as good as that from the Pocahontas seam of southwestern Virginia, shows a peculiar increase of sulphur in going westward, so that in the second basin it occasionally yields 1½ per cent of sulphur and 8 to 10 per cent of ash. This change is quite contrary to that which occurs in the overlying Upper Kittanning coal.

The lack of railroad development in central and northern Somerset County has resulted in relatively slight proving of the Allegheny coals in this territory, while the very important geographical advantage of the Berlin basin and the predominance of the Pittsburg coal in the Salisbury basin have led to a general neglect in their development. It would seem, however, from the known excellence of the Lower Kittanning, where mined in the first basin in the northern part of this county and the provings to the southward, that a large area of valuable fuel in the Lower Kittanning horizon, with a total thickness of about 4 feet, will be available in this region when the great coal bed of the Salisbury basin shall have been exhausted. A number of small mines along the Somerset division of the Baltimore and Ohio Railroad have been or are now operating upon the Lower Kittaning coal, but toward the south end of the first basin it can hardly be said to have been properly prospected. At one point in this region the seam is found to be 4 feet 6 inches in thickness with 3 feet 6 inches to 4 feet of coal, with a 1-inch parting 1 foot above the base and two knife-edge partings in the upper part.

The deterioration of the coal in passing from the First to the Second basin in Cambria County appears to be noted also in Somerset County, although, even in this Second basin, the thickness and quality of the fuel are still such as to justify exploitation for steam purposes. Thus, in the vicinity of Milford the coal preserves a good thickness, though somewhat irregular, and its product is highly esteemed for steam generation. Along the Casselman River the bed frequently attains a thickness of 4 feet, although it can hardly be said to average better than 2½ feet of clean coal in the small mines operating at this horizon.

The Lower Kittanning horizon is recognizable with a persistent but irregular coal in the Ligonier basin, in which, in southern Fayette County, it attains a thickness of 2 feet 6 inches, with a thin shale parting at the top. On the Youghiogheny River the coal is very shaly, though in the same basin in the northern part of the county it is of fair quality and workable. Along Chestnut Ridge it has not generally been recognized by the State geologists, but on the slope of Laurel Hill it is present and of considerable value. Here it has a thickness of 3 feet 6 inches to 4 feet, with an obscure middle parting which separates an upper bench of hard coal from the soft prismatic coal of the lower bench. Both benches carry considerable sulphur.

In Lawrence County the Lower Kittanning coal is reputed to be of no value, and in some sections it is not even recognized. It is found about 40 feet above the Ferriferous limestone in northern Butler, where it measures from 1 to 4 feet, averaging 3 feet in thickness, and is worked in several of the northeastern townships, though generally too thin for economic exploitation. The deterioration of this coal in passing westward is well marked in southern Butler and Beaver counties, in which the coal, when recognized, is thin and of no value, although the general persistency of the bed is attested by its discovery in a number of the deep borings in the southwestern corner of the State.

In the region northeast of Jefferson County the "Dagus" or "Daguscahonda" coal, the supposed representative of the Lower Kittanning bed, is a very valuable coal, it being the chief source of fuel in southern Elk County. Along Toby Creek it has been the source of a very large output, though a considerable portion of its best and most accessible area is exhausted. The latter circumstance has led to new development to the northward and eastward. In this region this bed is regular, ranging from 2 feet 11 inches to 3 feet 10 inches, with an average thickness of 3 feet 7 inches, the top layer being often bony. It is largely worked out in the St. Marys basin, where it averages about 3 feet 4 inches, locally reaching 4 feet, with about 2 per cent of sulphur. The coal ranges from 2 feet 6 inches to 3 feet 2 inches in the Clermont (Fifth) basin, though it is little developed in the Elk County portion of the basin. About Clermont, in McKean County, the area is small and thinly covered and has not been worked. In Cameron County, in portions of which this coal is present on the high lands of the basins, the bed has been worked. It has a thickness of 3 feet 6 inches in the Caledonia basin, and gives a red ash. A bed supposed to be the Dagus is mined at Tyler, in northern Clearfield County, with a thickness of about 3 feet 6 inches, and, after cleaning, it produces a bright silvery hard coke, said to be of superior quality.

The Dagus coal occurs in the top of a number of knobs in the eastern basins, in a portion of which it is nearly exhausted near the railroads. At the extensive Kettle Creek mines this bed is said to be 4 feet 6 inches to 5 feet thick and to possess high steam-generating power.[a]

In the outlying residual basins to the northeastward of the main coal field the celebrated "Bloss" coal[b] has generally been considered as identical with the Dagus (Lower Kittanning) coal.

This coal, so well known to blacksmiths and engineers of the Northeastern States and lower Canada, is derived chiefly from a dissected canoe-shaped basin about 20 miles long and 3 miles wide in eastern Tioga County. Prior to 1850 shipments of coal were being made from this basin, which still produces nearly 1,000,000 tons annually, drawn almost exclusively from this bed. At the Morris Run mines, now largely exhausted, the Bloss coal yielded 5 feet of clean coal, which gave the following analyses: Water, 1.120 per cent; volatile hydrocarbon, 18.570 per cent; fixed carbon, 72.097 per cent; sulphur, 0.583 per cent; ash, 7.630 per cent.

At Arnot, a few miles westward, the seam contains 3 feet to 3 feet 6 inches of clean coal, divided by thin partings into three benches, the lowest and purest of which contains 63 per cent of fixed carbon and 0.602 per cent of sulphur. The bed maintains the same dimension to the western end of the basin about Antrim, where the analysis gives 0.548 per cent of sulphur and 5.105 per cent of ash.

In the Ralston and McIntyre basins of Lycoming County a coal equivalent to the Bloss bed covers a number of square miles of the dissected plateau in the region of Ralston, on Lycoming Creek. The bed is here known as the "B" vein. It is fairly easily accessible, generally with sufficient cover, over a relatively large area in which it has been extensively worked on both sides of Lycoming Creek, although commercial activity is now confined to the western or Ralston area. In the McIntyre basin the Bloss coal is somewhat thinner than in the Blossburg basin, rarely averaging over 2½ feet of clean coal, though frequently exceeding 3 feet and sometimes attaining 4 feet in thickness, with a thick parting in portions of the territory. An average sample of the McIntyre product from this seam yields 0.636 per cent sulphur and 9.845 per cent ash. The coal maintains very nearly the same character in the Ralston basin, where it has in the main a thickness reported as averaging nearly 2 feet 6 inches and perhaps a slightly larger percentage of sulphur. The fuel is considered valuable for steam purposes and is largely devoted to railroad use.

The "Big bed," in the Little Pine Creek basin, in Lycoming County, has been referred also to the Bloss horizon. In this small basin, which is but partially developed, the "Big bed" reaches a thickness of from

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[a] Reported to be 12 pounds of water to 1 pound of coal.

[b] The Bloss coal is probably referable to the Mercer group. It is treated in this place in deference to the prevailing opinion respecting its correlation.

4 feet to 4 feet 3 inches, and locally 6 feet 11 inches, with 3 feet 8 inches of coal. It contains about 20 per cent of volatile hydrocarbons, 0.533 to 0.656 per cent of sulphur, and 11.325 to 14.695 per cent of ash.

To the Bloss coal is also referred the seam known as the "B" bed of the Barclay basin, lying in an irregular belt about 12 miles in length and 1 mile in width in southern Bradford County. The coal in this basin is now largely exhausted, except toward the eastern end and in some of the less-promising isolated knobs. At the old Gaddis mine it averages a thickness of 4 to 7 feet in four benches, of which the top bench, 8 to 10 inches in thickness, is a very bituminous coal; the second bench, 2 feet 4 inches in thickness; the third bench, 6 inches of fine blacksmithing coal, and the fourth bench, 1 foot 8 inches of good coal, with a bed of about 6 inches for the bottom. The best bench yields a fine grade of coal for smithing and forging, free from sulphur and with very little ash, making an excellent hollow fire. Usually the bed is in three benches, the top and middle being best, the entire seam often showing 5 feet to 5 feet 10 inches of good coal.

The exploitation in different parts of the basin shows a great variation in the thickness of the coal, even within a very short distance, but the general average for the seam shows 3 feet 4 inches of clean coal, which, in the six analyses from the Barclay and Schroeder mines, gives mean proportions of water, 0.822 per cent; volatile hydrocarbon, 16.999 per cent; fixed carbon, 69.593 per cent; sulphur, 0.702 per cent, and ash, 11.884 per cent.

In the Broadtop basin in Bedford and Huntingdon counties the Barnet coal, the most valuable seam of this field, appears to be the representative of the Lower Kittanning. This coal is persistent though irregular, and is especially valuable on account of the relative proximity of the Broadtop field to the Eastern market. It varies in thickness from 1 foot 9 inches to 5 feet, with an average of about 3 feet 6 inches. Locally, along Shoup Run, in the northern end of the basin, it reaches a thickness of 6 feet 9 inches, and at one point it attains the exceptional thickness of 17 feet 9 inches, although here it is very impure. It is the principal coal of the east Broadtop basin, where it has long been extensively mined about Robertsdale and Woodvale. In the vicinity of the latter place it measures 6 feet, with a bone top and 4 inches of bony coal near the middle. Its variability is illustrated by the fact that westward, in the same vicinity, the coal is said to thin to about 1 foot. Nevertheless it is probable that a considerable area of this coal in workable thickness is to be found in the flanks of the main Broadtop anticline, south of the Broadtop-Robertsdale road.

Throughout most of the area of the Barnet coal in both basins of the Broadtop field the seam is overlain at a distance of from 2 to 30 feet by a coal known as the "Twin bed." In the western part of the area the Twin coal seldom exceeds a thickness of 2 feet, but in the eastern part it sometimes furnishes 3 feet 6 inches of clean coal. In portions of the Robertsdale area and at several points in other parts of the field where it approaches sufficiently close to the Barnet coal, it is taken down in the same workings after removing the coal of the Barnet seam beneath it. The coal of the Barnet bed is very valuable as a steam coal, though rather high in sulphur and ash. The Twin coal is a clean, dry, open bed where thick enough to be eventually worked independently, or close enough to be at present removed with the Barnet. It has not enough volatile matter on the whole for cooking purposes, while the amount of ash sometimes reaches 10 per cent and the proportion of sulphur often approaches 1½ per cent.

MIDDLE KITTANNING COAL (C).

The Middle Kittanning coal lies about 30 to 50 feet above the Lower Kittanning (B) and about 45 feet below the Johnstown cement bed, the interval being usually occupied by shales. On account of its nearness to the Lower Kittanning horizon its outcrop zone is largely the same as that of the latter coal. The Middle Kittanning is generally too thin and too dirty for mining, and it is not only the poorest coal of the Kittanning group, but is, perhaps, the least important of the coals in the Allegheny formation. It is found in its best condition and development, as will be seen, in the northern and eastern portions of the main field. In the small northeastern outlying areas and isolated basins the horizon has not been recognized.

In the type section, at Kittanning, the Middle Kittanning coal is but a few inches in thickness, and it does not appear to be of commercial value elsewhere in Armstrong County. Northward, however, it is reported to be somewhat better, and it is nearly 3 feet thick and of better quality in the southern townships of Clarion County, where it is divided by a shallow parting into two benches. In Indiana County it is found to be 2 to 5 feet thick locally, but over most of this territory it is thin and unworkable as well as often pyritous, though mined at a number of points for local use. The better condition noted in Clarion County appears to continue eastward into Jefferson County, in the central portion of which it reaches 3 feet or even 4 feet in thickness. In this county the coal, which is low in sulphur (0.890 per cent) but rather high in ash (8.700 per cent) is mined for local use over a considerable area, though it is not exploited on a commercial scale on account of the nearness of the magnificent Reynoldsville Lower Freeport bed. From such tests as have been reported, it appears probable that the Middle Kittanning will eventually, when developed, form an important source of fuel in this county, over the greater part of which its horizon is readily accessible.

The Middle Kittanning is reported as measuring about 2 feet in the

Fifth basin in Elk County. In Center County it sometimes reaches a thickness of 4 feet, but it is here too shaly for economical mining.[a]

Through northern Clearfield County the Middle Kittanning is said to be 1 foot 6 inches to 3 feet thick and to carry partings which render it of no present value, though in certain localities in this region it is reported to contain coal 3 feet in thickness and of a good quality. Near Osceola, on the eastern border of the county, the bed, 2 feet 6 inches in thickness, is very dirty and at a level of about 30 to 35 feet below the Upper Kittanning and 30 to 40 feet above the Lower Kittanning coal.

In the First basin in eastern Cambria County it is generally either thin or dirty; but above Johnstown, in the Second basin, where it appears to be of greater value, it becomes thicker, reaching a measurement of 9 feet locally, and purer, though it is still too sulphurous to be ranked with the higher grades of coal. It is dirty where opened in the Berlin-Wilmore (First) basin in Somerset County, and little better can be said of its continuation in the Somerset portion of the Potomac basin. Its quality seems to be no better to the westward, and in the Ligonier basin of Westmoreland and Fayette counties it is reported to be thin, impure, and nowhere of value. Farther north, however, in Butler County, the Middle Kittanning is said to be persistent and of good quality, though generally of hardly workable thickness except near the northern border, where it averages from 2 to 4 feet. In the eastern part of the county it is fairly persistent, with an average of about 2 feet of coal, and is locally thickened at one point to three benches of 2 feet, 2 feet, and 6 inches, separated by 6-inch and 1-inch shaly partings. Although a thickness of 6 feet of this coal is reported in a bore hole in the western part of Butler County, it is generally thin and worthless where recognized along its outcrops. In Lawrence County the bed seems to be of little value; and it is but little better in Beaver County, where a coal supposed to belong to this horizon thickens to 2 feet 2 inches above Beaver Falls, its bottom bench, 1 foot 7 inches thick, having been mined and coked to some extent. Farther southward the coal appears to be either thin—about 2 feet 5 inches—or too sulphurous to be of any commercial importance.

In the northeastern basin the Middle Kittanning horizon is not definitely recognized. The coal supposed to represent this horizon in the McIntire basin of Lycoming County is reported to have a thickness of 6 feet to 9 feet 6 inches, by far the greater portion of which is bone, shale, and sandstone. No seam of workable dimension appears to be present at the middle Kittanning level in the Blossburg basin, while the Gaines and Barclay basins in Potter and Bradford counties are hardly of sufficient depth to contain it. In the Broadtop coal field

[a] The increase of shaly impurities in the lower beds of the Coal Measures in passing toward the margin of the Coal Measures trough is illustrated in this bed as well as in the coals already discussed.

the Middle Kittanning is not definitely identified, but it is possible that the seam known as the Twin bed, about 12 to 37 feet above the Barnet coal and sometimes mined with the latter, may represent the horizon under consideration.[a]

Between the Middle and the Upper Kittanning horizons another coal, known as the Gorman coal, occurs, with a persistent extension over a large territory, though it is not traceable throughout the greater portion of the field, as are the principal coals of the Allegheny formation. The Gorman coal is exposed locally in Center County as a 2-foot bed, often of lustrous peacock coal, although in most districts it is very inferior at its best. The bed is traceable in Clearfield, Cambria, Indiana, and Jefferson counties; it is rarely over 2 feet in thickness, and is nowhere commercially exploited. At Johnstown it is only about 6 inches in thickness.

UPPER KITTANNING COAL (C′).

The third and topmost coal of the Kittanning group lies almost immediately above the Johnstown cement, 135 to 190 feet above the Ferriferous limestone and about 80 feet to 100 feet below the Mahoning sandstone. Owing to its distance from the base of the series and the generally shaly character of the intervening beds, the Upper Kittanning does not extend so far out as the lower coals of the Allegheny formation on the long spurs and projecting ridges supported by the sandstones of the Pottsville formation. It is therefore generally absent from the shallow basins and detached patches of Coal Measures which cap the knobs along the northern border of the main field. Its outcrop zone is greatly reduced and more largely confined to the margins of the deeper basins, in which, however, on account of its relative nearness to the Freeport and Mahoning sandstones the bed is more often sure of cover within its outcrop in the escarpment slope beneath the above-mentioned sandstones.

In the value of its production the Upper Kittanning is fourth in importance of the Allegheny coals. It is somewhat remarkable for the variety of its composition as well as for its patchy mode of occurrence. It is the horizon of most of the cannel shale, or so-called cannel coal, yet the areas of this bastard cannel are very restricted and isolated. In Beaver County, where it is known as the "Darlington coal" and the "North Washington cannel coal," it contains 6 to 12 feet of cannel in a small area. To the same horizon belongs the "Woodland cannel" of Clearfield. It is represented in Center County by the "Big bed" of coking coal in the Snowshoe basin, and its horizon appears to include a block coal in Somerset County.

In the vicinity of the type locality (Kittanning) the Upper Kittanning bed has a thickness of from 6 inches to 1 foot 6 inches, and

[a] The Twin coal has already been referred to in the notes on the Lower Kittanning coal, pp. 152-153.

throughout the county it is generally valueless and unworkable, rarely showing 2 feet 6 inches of good coal; but near New Bethlehem, in the northeastern part of the county, it shows an extraordinary dilation, the section of which is as follows: Lower bench, bituminous coal, 4 feet; second bench, cannel, 8 feet; top bench, bituminous, impure, 1 foot 11 inches.

A singularly notable feature of the occurrence of the cannel is its introduction in many cases as a lens either between the benches of bituminous coal or superimposed directly on the top of the bituminous seam, whose thickness and regularity are not otherwise frequently disturbed. The cannel shale and thin coals southeast of New Bethlehem have been mined to some extent and hauled by wagon for special shipment to gas factories.

In Indiana County the Upper Kittanning becomes thicker and is variable in composition. Though often thin or even unrecognized in the southern portion, it is reputed to be 4 feet thick in Black Lick Valley, and from 18 inches to 3 feet in the Ligonier basin, in which it is mined to some extent, though it contains considerable earthy matter. Northeastward it is of better quality, the lower of the two benches being highly esteemed as a smithing coal. The upper bench usually contains more earthy matter. Near Marion, in the northern part of Indiana County, the coal and upper bench of cannel shale cover a small area, in which at one point the bottom bench preserves its ordinary thickness of 2 feet 7 inches of pure friable smithing coal, covered by 8 feet 3 inches of cannel shale, which at some distance becomes transformed into tough black shale. The bastard cannel carries about 24.485 per cent volatile hydrocarbons, 52.964 per cent fixed carbon, 0.621 per cent sulphur, and 21 per cent ash. The soft underlying bituminous bench contains 30.320 per cent volatile hydrocarbon, 66.83 per cent fixed carbon, 0.654 per cent sulphur, and 1.623 per cent ash. Although frequently of workable thickness in this county, the Upper Kittanning is rarely found to have a commercially workable thickness of clean coal. It is much used by farmers for calcining the Johnstown cement limestone, which usually underlies it by but a few inches.

The Upper Kittanning extends through a large part of Jefferson County, but it is thin and worthless over most of the area, usually falling short of 18 inches. In the western part of the county, where it is best, it rarely reaches a thickness of 3 feet. In Center County the principal coal, the "Middle" or "Big" bed, ranging 5 feet to 7 feet in thickness, appears to lie at the Upper Kittanning horizon. In the Snowshoe basin this coal is in three benches, with two partings of 6 inches and 2 inches and a top bench of bone or cannel of a thickness of 10 or 12 inches. It contains 4 feet 6 inches to 5 feet of good coal containing 70 per cent of fixed carbon, 1 per cent of sulphur, and 3.5 to 7 per cent of ash. In this basin the fuel of the seam, which is now nearly exhausted, is a rich, bright, heavy coal, which, when carefully cleaned, makes an excellent coke.

In Clearfield County the Upper Kittanning bed ranges in thickness from 1 foot 6 inches to 5 feet, with an average of about 2 feet for the whole county. It is generally thin in the eastern basin, where it lies 40 to 50 feet below the Lower Freeport coal, but westward it improves both in quality and thickness, the latter varying from 3 to 5 feet, often with one or more partings. The coal is excellent in the vicinity of Curwensville, and is said to have a thickness of 4 feet of clean coal at Westover. Although the coal does not appear to be so good as in the Snowshoe basin, in Center County, the same bed in Clearfield contains a coal of excellent quality. It is but little exploited at present, and therefore offers a large area in the central and southwestern portions of the county over much of which good coal of a thickness of 3 feet to 3 feet 6 inches may be mined when the thicker upper coals of the Phillipsburg-Houtzdale basin shall have been exhausted.

Along the first (Wilmore) basin in Cambria County the horizon of the Upper Kittanning coal is of minor importance; for although often of workable thickness it is generally less pure to the eastward, just as has been noted in eastern Clearfield County. However, it is worked at three mines on Trout Run, along which it shows in places a thickness of about 6 feet, with 3 feet 8 inches to 4 feet of good coal, but the product is not so good as that of the Miller (Lower Kittanning) or the Lemon (Upper Freeport) coals. In the region of Frugality the bed is workable, but too impure for competition with the other coals.

The Black Lick coal in the northwestern corner of the county is regarded by many as belonging to the same horizon, though on account of its composition and occurrence in a double bench with columnar cleavage, similar to the occurrence of the Lower Kittanning coal, it is regarded by some geologists as representing the latter. In Black Lick township this coal has a thickness of 4 feet and is of excellent quality.

The Upper Kittanning is known as the Cement seam about Johnstown, where it is a bright, horizontally bedded coal, averaging about 3 feet 6 inches in a solid breast, which has long been extensively mined for the furnaces in that district. As in Clearfield County, the coal is much better in the second (Johnstown-Somerset) basin, though it carries considerable (1.25 to 1.50 per cent) sulphur, which, however, is segregated in masses and is easily removed.

The Cement (Upper Kittanning) and the Miller (Lower Kittanning) are the principal coals of northern Somerset County, the former being especially important in the Second (Johnstown-Somerset) basin, in which it compares favorably with the Miller coal of the Scalp Level (Windber) district in the First (Berlin-Wilmore) basin. In the latter basin the Upper Kittanning, though somewhat impure, nearly everywhere shows a thickness of 3 feet, occasionally increasing to 7 or 8 feet, of which 4 feet 6 inches to 5 feet is reported as salable.

Near Garrett, in the southern part of the county, in the same basin, the seam is said to have a thickness of 6 feet 6 inches of coal, of indifferent quality. The "rock vein," 4 feet in thickness, in the northern end of the Potomac (Wellersburg) basin, is thought to belong to the same horizon. In the Second (Johnstown-Somerset) basin the Upper Kittanning generally measures 3 feet to 4 feet of good coal in one bench. On the Quemahoning Creek the bed shows a section containing 4 feet in one bench, said to contain 75 per cent of fixed carbon, 0.519 per cent of sulphur, and 6.545 per cent of ash.

The same seam carries 3 feet 7 inches to 3 feet 10 inches of clean coal near Bethel and about Hooversville. It is also mined at Snyder, where it has a thickness of 4 feet 6 inches to 5 feet. An analysis shows that it contains 76.5 per cent of fixed carbon, 0.63 per cent of sulphur, and 4.51 to 4.85 per cent of ash.

It is the most valuable coal in the vicinity of Milford, reaching at one locality a thickness of 7 feet. Passing southward, the seam occurs in two benches, the upper bench soft and columnar, the lower dull, compact, and blocky, making a fine steam coal. Along the Casselman River the coal referred to this horizon is the most important bed worked at present, locally attaining a thickness of 6 feet 6 inches. Though somewhat dirty and pyritous, it is easily mined and is well suited to domestic use.

Near Casselman village the parting of shale and bone increases to 2 feet 6 inches in thickness, and here 2 to 3 feet of good coal is available in the upper bench. From this vicinity westward the coal generally carries a higher percentage of sulphur. In southern Somerset County the Upper Kittanning coal is but little developed on account of its reported greater impurity and the disadvantageous geographic position with reference to the coals of the Berlin and Salisbury basins.

In the Ligonier basin the Upper Kittanning coal does not appear to have generally been recognized in Fayette County, though in eastern Westmoreland it is present, but thin. Toward the northeast corner of the county it thickens rapidly, so that it is reported as reaching a local thickness of nearly 5 feet.

In Beaver County the coal ("Darlington") of this horizon is irregular but persistent north of the Ohio River. On Big Beaver River its section contains 2 feet 5 inches in an upper bench separated by 1 inch to 1½ inches of shale from a lower bench. The coal here is of a high grade, rich in volatile combustible, and has been mined extensively. Near Homewood it thins to 18 inches, but thickens again to 3 feet of excellent coal above New Brighton. Southeast of this point it is seldom over 18 inches thick in its exposures, though locally very pure and much sought by blacksmiths. Its average thickness over the northern part of the county appears to be approximately 2 feet 5 inches.

A remarkable development of this coal is found on the I. F. Mansfield property, in Darlington Township, of this county. At this point this variable coal is usually in three benches, the base 6 inches to 1 foot of bituminous coal, the middle 6 to 12 feet of cannel coal, merging into a mass (top bench) of cannel shale reaching a thickness of 6 feet. The cannel coal is a purely local development, and as it thins away the bituminous bench thickens, so that it measures 2½ to 3 feet at a nearby locality, where it has been mined for gas and marketed as the Beaver block coal. The cannel coal averages 7 feet in thickness in this small area and is of moderate quality, though high in ash.

In northern Butler County the horizon of this seam lies 110 to 130 feet above the Ferriferous limestone. The coal is generally good and is largely workable throughout the county, seldom exceeding 4 feet and averaging approximately 3 feet in thickness. It furnishes a good bituminous coal, measuring from 2 to 4 feet in thickness in several townships, in two of which, Washington and Venango, it is accompanied by a thin cannel coal said to be of good quality. In the southern part of the county the "No. 4" on the Ohio and the "Creek vein" on Slippery Rock Creek are said to represent the Upper Kittanning. This coal is the chief coal of western Butler County, ranging from 2 feet 4 inches to 7 feet in thickness, typically occurring in a section with a thickness of from 2 feet 9 inches to 3 feet 4 inches, with a 1-inch parting.

In Lawrence County this coal, though variable in character, is the most important and persistent of the series, and underlies about half of the county. Its thickness usually ranges from about 2 feet to 4 feet, but over much of the area it averages from 2 feet 6 inches to 3 feet. Nearly always it has a thin parting, varying in its position. Along Big Run and Beaver River it is a high grade of mill and gas coal. From its purest state in Shenango Township it deteriorates to a more sulphurous coal in Slippery Rock Valley, but on reaching Plain Grove Township it appears with a section of 4 feet thick, the upper half being a block coal that was formerly somewhat extensively used in the raw state at the local furnaces. The seam is not so good north of Newcastle, though it is of workable thickness, with a rather large area between the Chenango and Neshannock creeks.

The bed supposed to represent the Darlington coal in Mercer County lies less than 100 feet above the Ferriferous limestone, and embraces an area of about 50 acres on the knobs in the southeast corner of the county. The coal, 3 feet 2 inches in thickness, including a 2-inch parting, is slaty and pyritous, but is mined for local use.

The analyses of the coal from the Upper Kittanning horizon in the Fairmont, Snowshoe, Somerset, and Darlington districts are given in the table on page 184.

LOWER FREEPORT COAL (D).

The lower Freeport coal is, next to the lower Kittanning, the most important of the coals of the Allegheny formation in Pennsylvania. For a number of years prior to 1898 it led in production among the Allegheny coals. Its yield amounted to about 10,000,000 tons in 1900. This enormous output is derived almost entirely from two areas: (1) The Reynoldsville basin, including the eastern portion of Jefferson County, the northeast corner of Indiana County, a small portion of northwestern Clearfield County, and a small area in southwestern Elk County; and (2) the Phillipsburg-Houtzdale basin along Moshannon Creek in eastern Clearfield County and the southwestern border of Center County. Over most of the remainder of its territory this seam is either worthless or of too low a grade for competition in the present market.

The position of this coal is 30 to 80 feet below the Mahoning sandstone, and from 6 inches to 15 feet above the lower Freeport limestone, which, though absent in portions of the field, is present throughout the greater part of the area and constitutes the chief key rock for the determination of the horizon. This coal is generally eroded from the knobs and ridges near the northern border of the coal field, as well as from most of the detached areas and isolated basins. It is now for the most part restricted to the slope of the Mahoning sandstone escarpment along the flanks of the deeper basins. The seam is usually broken up into two or more beds by partings which are sometimes so thick as to destroy the value of the bed. At other times the upper portion grades locally, especially in the Allegheny Valley, into a thin, low-grade cannel. It is the source of the fuel which has given the Reynoldsville basin its great reputation, and is found in its best condition in the region of Reynoldsville and Punxsutawney, in the eastern and southeastern portions of Jefferson County. About Reynoldsville the coal, which is somewhat irregularly interrupted by thin partings, is usually in two benches, the entire seam measuring from 4 to 7 feet, often carrying from 4 to 6 feet of clean coal. The fuel from this vicinity is marketed as high grade gas coal, the analysis giving fixed carbon 62.524 per cent; volatile hydrocarbon, 30.800 per cent; sulphur, 0.776 per cent; ash, 4.800 per cent.

Locally the seam is greatly thickened, but such increase is generally accomplished by the introduction of partings and bony layers, to the detriment of the commercial value of the bed. About Punxsutawney the Lower Freeport averages 5 feet in thickness, sometimes carrying 6 feet of good coal in one bench. In this region are some of the largest mines in the State. The fuel is usually coked and produces a high-grade product, over 500,000 tons being shipped from this district in 1900. Westward through Jefferson County the coal is of workable thickness generally, though not of the exceptional quality shown in the Reynoldsville basin. From the Reynoldsville region it thins to the northeastward, while at the same time it deteriorates somewhat to the westward and southwestward. It is of excellent quality at Brockwayville and at Shawmut, in Elk County.

The Punxsutawney district extends for some miles into northern Indiana County, where the Lower Freeport is still of good quality, with from 3½ to 4 feet, or sometimes 4 feet 5 inches, of good coal. Westward and southward, however, the seam thins in Indiana County from about 3 feet 8 inches to 2 feet, and though worked to some extent in the western part, where it lies 60 feet below the Mahoning sandstone, it is generally of poor quality, with an average thickness of about 2 feet 6 inches over most of the county. Occasionally a few inches of cannel coal occur as a top bench of the seam in this county, but the bed as a whole is generally either too much broken up by partings or too impure for commercial exploitation.

In Armstrong County this bed lies from 40 to 50 feet below the Mahoning sandstone. In the southern part it is rarely over 2 feet in thickness, and usually dirty when thicker. In the central and northern portions of the county it is locally better, and is mined somewhat, though rarely reaching a thickness of 4 feet of clean coal, except in the northeast corner, toward Jefferson County, where, near Fairmont, it presents a thickness of from 6 to 7 feet of gas coal of excellent quality. Locally the bed increases to a thickness of 13 feet 5 inches at one point northeast of Kittanning, but in this section only 3 feet 8 inches is clean coal. In the vicinity of its type section in the southwest corner of Armstrong County the Lower Freeport coal is locally a semicannel, but the bed is generally shaly and impure.

The horizon of this coal is present in the knobs of the southern townships of Clarion County, and presents a thickness of from 6 to 7 feet, the upper benches being of inferior quality. About Fairmont, where it is mined for gas, the fuel contains 35 to 40.5 per cent of volatile hydrocarbon and 6.645 to 6.220 of ash. When washed to remove the sulphur (1 to 2 per cent) it has been coked to some extent. Westward, in the area more remote from the fine development of the Reynoldsville basin, the quality of the coal becomes more inferior in approaching the Allegheny River.

The Tobey basin, in southwestern Elk County, is the continuation of the Reynoldsville basin of eastern Jefferson County. Although the seam is somewhat thinner at Brockwayville and to the northeast, it is extensively operated in the vicinity of Shawmut, in Elk County, where it furnishes an output of more than 2,500 tons daily. Here the bed lies 130 feet above the Dagus coal, and carries from 3 feet to 4 feet 6 inches of coal without partings. It is a first-class steam coal, low in ash and sulphur. A large amount of lump coal is produced, while locally the bottom clay is mined for the manufacture of pressed brick.

The Lower Freeport coal has been eroded from the northern portion of Elk County and is absent in the Caledonia basin of the southeastern portion of the county.

The horizon of this bed is found in a few knobs only in Center County, and it is thin, though generally of good quality in this region. In the Snowshoe basin it is hardly more than 2 feet in thickness. On the eastern flank of the Phillipsburg-Houtzdale basin it is found on the slope of a few knobs of small area on the Center County side of Moshannon Creek. In this region the coal, which has thickened slightly in the direction of the basin, and which is well known as the "Moshannon" bed, presents a section of 4 feet 5 inches to 5 feet of bituminous coal, covered by 2 inches to 3 inches of cannel bone, 1 foot of soft coal and 2 inches to 4 inches of bone. The lower bench, which gives the coal its reputation in the Moshannon Valley, is a clear, fine steam coal, like that of Jefferson County.

The Moshannon bed is the chief coal of Clearfield County. It is worked on the western border near Dubois, in the Reynoldsville basin, at a depth of 265 feet, the coal being generally but little thinner (5 feet 6 inches to 6 feet of clean coal) eastward than on the Jefferson side of the line, though it reaches a thickness of 7 feet at one point.

In the northeastern portion of the county it occurs in the high knobs of Karthaus Township with a reported thickness of 5 feet to 5 feet 6 inches of good coal. It ranges from 2 to 7 feet, averaging from 3 feet to 3 feet 6 inches in thickness and is of good quality in portions of twelve townships in the central, southern, and western parts of the county, but it is in the Philipsburg-Houtzdale basin that this bed shows its greatest purity and excellence in this county. In the central part of this basin the Moshannon coal measures from 3 to 7 feet, usually 4 to 5 feet. Northeastward it contains a 1 or 2 inch parting 6 to 15 inches above the floor. Near Houtzdale the bed is nearly all clean coal, yielding 76.5 per cent of coke. Still farther south the coal is split, the lower bed, 2 to 4 feet thick, being clean and good. A typical analysis of this bed in the Philipsburg-Houtzdale basin shows 72 per cent of fixed carbon, 0.58 per cent of sulphur, and 3.6 per cent of ash.

The great purity and utility of the Moshannon coal, which, prior to the exhaustion of large portions of the district, led to the production in 1899 of nearly 5,000,000 tons of coal and 200,000 tons of coke in this basin, makes it the standard coal of the Allegheny front region.

The Moshannon coal continues to thin in passing along the First basin toward the northern Cambria County line, near which it measures over 3 feet 6 inches and is of good quality; but at Frugality and Sandy Run, in northern Cambria, it loses its superiority, though it is said to still furnish 3 feet 2 inches of excellent steam coal at Mountaindale, in the northeastern corner of the county. About Patton and in the two other basins to the westward it is the chief coal. In this region it has an upper mining bench about 3 feet 6 inches to 4 feet in thickness above a shale and bone parting measuring 4 to 6 inches, which overlies 1 foot of bottom coal. Another section gives an upper bench of 3 feet 9 inches to 4 feet 2 inches, resting almost directly on 1 foot 6 inches of impure coal.

In the southern two-thirds of Cambria County the Lower Freeport becomes thin and unimportant, while the Upper Freeport, which is thin or worthless in northwestern Cambria, thickens as the lower bed thins, especially to the southeastward and along the First basin. In southern Cambria the Lower Freeport is usually less than 3 feet thick, and in the unusually thick section at Sonman it is said to contain but 2 feet 10 inches of coal under 3 feet of bone. It is known as the "limestone" bed about Johnstown, in the Second basin, where it averages about 2 feet 6 inches in thickness. Farther south the bed can hardly be relied on for more than 2 feet of good coal.

The decreased thickness of this coal observed in southern Cambria County continues in general throughout Somerset County, over which the bed is hardly better, it being generally but little more than 2 feet 6 inches thick, though ranging from 2 feet to 4 feet 6 inches locally, especially in the northern part of the county; but where thick its dirty character seriously impairs its value. About Garret the bed is said to average 2 feet 8 inches to 3 feet of coal in one bench. A little farther west, in the Milford district, Somerset-Johnstown basin, it furnishes 2 feet 6 inches to 3 feet of bright, rather soft, easily mined coal. Still farther west, along the Castleman River below Rockwood, it is reported as variable and thin, seldom exceeding 2 feet 6 inches in thickness. Borings in the west-central part of the county show an average thickness for the bed of about 2 feet 6 inches. In general, throughout the most of Somerset County this coal is of little or no present commercial value, though it is locally mined to a considerable extent for burning the underlying limestone.

In the Ligonier basin of Fayette and Westmoreland counties the Lower Freeport is almost everywhere variable and unreliable. Toward the north it is thin, rarely exceeding 2 feet in thickness, but farther south it shows in a few instances 4 feet 9 inches of good coal. In general it ranges from 1 foot to 7 feet, with thick partings and much inferior coal in the thicker sections. It has in some instances been observed to decrease from 3 feet 6 inches to 1 foot 5 inches in a very short distance. The bed is very dirty, though reported to be of locally workable thickness in southwestern Fayette County, and it is generally of no value in the Blairsville basin and farther west. Over certain areas it has not even been recognized, and it is reported absent on the Conemaugh, though said to be locally 3 feet thick and of fair quality on the Loyalhanna.

In Beaver County the bed is generally of little intrinsic value, though on account of its geographic position it has been worked at a number of points. It is well exposed and persistent near Baden, in the eastern part of the county, where it has been mined, the seam carrying 2 feet 6 inches of rather dirty and poor coal. At one point it is said to afford 4 feet of impure cannel.

The Lower Freeport is very irregular in thickness in northern Butler County, over most of which it has more than 2 feet of coal, but it is generally of poor quality. It is said to be best in Clay, Concord, Washington, and Parker townships, where it locally measures 14 to 16 feet, though only a portion of this thickness is good coal. At best it is hardly over 5 feet, parted by 1 foot of shale, in southern Butler, where it is recognized as the "Schantz" coal and the "No. 5 vein" of Ohio. The bed is both thin and dirty where exposed, its best section being perhaps near the mouth of Breakneck Creek, where it has a thickness of 2 feet 6 inches to 3 feet.

The Lower Freeport improves slightly in the knobs of southern Lawrence County, where it has its final outcrop. Here it is 65 to 70 feet below the Mahoning sandstone and has been opened at a number of places. At one locality it shows the exceptional thickness of 6 feet of bright, richly bituminous smithing coal. On the whole, however, the bed is of very little commercial importance in this county.

The horizon of this bed is not noted in the projecting spurs or outlying patches along the northern border of the coal field over most of the First and Second basins. It is probably wanting in the Blossburg basin and is certainly absent in the Barclay basin. In the McIntyre-Ralston basin of Lycoming County the bed, 80 to 90 feet below the supposed Mahoning sandstone, which usually has been referred to this horizon, contains 5 to 11 feet of shale and impure coal, too dirty and too thinly covered for successful exploitation, even with the great advantage of the geographic position of the district. The coal is not recognized in the Broadtop coal field of Huntingdon and Bedford counties.

The horizon of the Lower Freeport bed offers large areas, either in slightly inferior condition or under relatively thick cover, for exploitation when the needs of the trade shall bring it into requisition. Considerable areas, over which the coal is of good quality, are available in southern Jefferson County and below the Conemaugh formation in southern and western Clearfield County, while in its less pure condition, suitable for steam purposes, it will doubtless at some time be mined over large areas in Somerset, Westmoreland, and Indiana counties. Analyses of the fuel from the Lower Freeport coal will be found on page 184.

UPPER FREEPORT COAL (E).

The Upper Freeport, the highest of the Allegheny coals, lies just beneath the Mahoning sandstone, the lowest member of the Conemaugh formation. It is a variable and complex bed, extending in gross workable or nearly workable thickness over most of its area, although over a considerable portion of this territory it is too much broken up and too impure for profitable mining. It has generally been eroded from the northern marginal portions of the field, though it is well exposed far down into the basins along the deep waterways and along the anticlinal ridges. In certain areas it appears to be totally absent, while in others it is injured by contemporaneous erosion or stained by the percolation of water through a coarse sandstone roof. Usually the coal is tender, crushing in handling, but when in this condition it is apt to coke well in certain districts. It is the Lemon coking seam along the Allegheny front, in eastern Cambria County, where it thins and becomes shaly in passing southward to the Maryland line. It is sulphurous in the Ligonier basin. In the vicinity of its type locality it carries one or more thick partings. In the Broadtop coal field it is supposed to be represented by the Kelly coal, which is there very important and extensively mined in Bedford County, though thinning to less than 2 feet, and even sometimes unrecognized a few miles to the northward in Huntingdon County.

In Armstrong County the Upper Freeport is fairly uniform and persistent. It is the principal source of coal along the Kiskiminitas River, in the southern part of the county below Apollo, where it is finely displayed, and ranges from 3 to 6 feet, with an average thickness of about 4 feet, including thin partings. Here it carries considerable sulphur, which sometimes amounts to 2 per cent. Northward it averages about 3 feet 6 inches in thickness, and though variable locally is good in certain districts, as, for example, about Pine Furnace (4 feet 1 inch), along Mahoning Creek (4 feet), and near Bradys Bend (3 feet 6 inches). It is a good fuel for steam purposes in the southern portion of the county, where it occasionally furnishes a block coal for locomotive use.

The horizon of this coal occurs in the knobs only of the southern townships of Clarion County, where it ranges from 2 feet 6 inches to 4 feet 3 inches in thickness and has been mined to some extent near the railroad. Though sulphurous and somewhat dirty, it was formerly worked near Bradys Bend. In Porter Township it contains 4 feet to 4 feet 9 inches of fine coal, which was formerly coked for use in the furnaces in the vicinity. The Porter coal contains much mineral charcoal, swells but little, and holds its shape like a block coal. The analysis shows fixed carbon, 54.448 per cent; sulphur, 0.672 per cent, and ash, 8.040 per cent, the fuel ratio being 1.54.

In Jefferson County the coal of this horizon is generally shaly, pyritous, and unreliable, though reaching a thickness of 4 feet in places. In general the coal in this county is of a quality hardly good enough for the present market; but it is much better toward the northeastward in the vicinity of Brockwayville, where it will doubtless eventually be worked, though at present it is overshadowed by the Lower Freeport coal of the same (Reynoldsville) basin.

In Indiana County the Upper Freeport is the most important coal, and though usually of slightly inferior quality it is accessible and thick, locally attaining a thickness of 8 feet, with two shale partings, along the Conemaugh River. The coal is coked near Graceton. About Lockport it is 8 feet 3 inches thick and is extensively mined in a section as follows: Upper bench, 3 feet 6 inches, including 1 inch of shale 6 inches below the top; main bench, 3 feet 6 inches, with a thin parting near the floor, followed by 9 inches of bone; 3 inches shale parting; lower bench, 3 inches. The main bench is mined. The upper bench is pure, though soft and friable. Analyses of the Lockport coal shows 0.588 per cent of sulphur and 2.385 per cent of ash. The coal is usually variable as to sulphur and ash, but in the Blairsville basin the main bench carries over 3 feet of coal, giving approximately, volatile hydrocarbon, 27.800 per cent; fixed carbon, 67.537 per cent; sulphur, 0.718 per cent; ash, 3.175 per cent.

The structure of the seam at this point is to a large exent typical of the region.

The Upper Freeport horizon appears to be caught only in the Shawmut basin in Elk County, where, continuing northeastward from Brockwayville in Jefferson County, it measures 6 to 12 feet, including partings. Here, as in Jefferson County, the coal, though good in quantity, is inferior to that of the overshadowing Lower Freeport, which predominates. The coal noted in the hilltops of the Tangascootac basin in Clinton County, and supposed to represent the Upper Freeport horizon is in two benches of 2 feet 6 inches each, with a 4-inch parting, the fuel being very pyritous. In Center County the Upper Freeport caps the hills of the first and second basins. Though often troubled with rolls, it is said to average 5 feet in thickness, with 2 inches to 3 inches of shale parting in the middle. The coal, which is nearly exhausted in this vicinity, is a bright columnar, clean fuel which cokes well.

In the Philipsburg district of Clearfield County this seam is from 3 feet 6 inches to 3 feet 8 inches thick. In the Houtzdale district it is 2 feet 6 inches to 3 feet, and the latter thickness apparently prevails through the central portion of the county. In general the bed is dirty or sulphurous; but in the Houtzdale district, where it usually furnishes clean, bright coal, it has less sulphur. It is mined at a number of points, though over considerable areas it is seriously damaged by the removal of the Lower Freeport, which in this region lies but 30 feet below it. Analysis of a good sample of this coal shows 68.400 per cent of fixed carbon, 1.900 per cent of sulphur, and 4.500 per cent of ash. The bed ranges from 2 to 4 feet in thickness, averaging about 3 feet throughout the county, and may eventually be relied upon for the production of a great mass of slightly sulphurous fuel in this district.

The Upper Freeport coal retains its somewhat indifferent condition from southern Clearfield County southward into Cambria County, where it rapidly improves, especially in the first basin, so that the bed becomes, next to the Miller (Lower Kittanning) coal, the most valuable seam of Cambria County. In the vicinity of Frugality, in the first (Wilmore) basin, in northern Cambria, it becomes important, containing nearly 3 feet 6 inches of clean coal that cokes satisfactorily when carefully prepared. Usually it carries 2 inches of cannel bone near the top, in this respect resembling its condition in Indiana County. Northward the bed is poorer, it being only 3 feet thick near Mountaindale. It is extensively mined both by drifting and shafting near Gallitzen. Here it is somewhat sulphurous in the upper bench, and, contrary to the general rule of progressive increase in volatile hydrocarbon in passing westward, its proportion of volatile hydrocarbon is larger than that found in the same coal a short distance to the westward. In this respect it repeats the condition already noted in the Miller coal about Bennington and Gallitzen. At Webster, on the west side of the Wilmore basin, the Upper Freeport bed shows 3 feet 10 inches to 4 feet 1 inch of coal, with 2 inches of shale 1 foot 6 inches above the floor.

In the vicinity of Johnstown this bed is known as the "coke yard" or the "Lemon seam." Hereabouts it measures 3 feet to 3 feet 6 inches, locally exceeding 4 feet in thickness, with some bony coal and a parting near the floor. The fuel here is of good quality, though soft and tender. On the head of the South Fork of the Conemaugh, in southeastern Cambria County, the seam is badly cut up by partings, but borings indicate a good thickness in the deeper portions of the Wilmore basin. On the whole the coal of this horizon in Cambria County is hardly so highly prized for smithing or rolling-mill work as the Lower Kittanning, on account of the higher percentage of sulphur.

In its better condition, in eastern Cambria County, the coal of this bed compares favorably with that of the Lower Freeport in northern Cambria, Clearfield, or Jefferson counties. It has a good reputation, though it is not worked so extensively as the rather purer and more accessible Miller bed. A large territory of the Upper Freeport in workable thickness and but slightly inferior condition will no doubt eventually be developed in Cambria and Clearfield counties, when the advanced exploitation of the Miller bed leads to the development of the other coals.

In Somerset the Upper Freeport retains nearly the same characters as in southern Cambria County. In the Berlin-Wilmore basin it ranges in thickness from 3 feet to 3 feet 10 inches, with an average of about 3 feet 6 inches of coal, including a thin parting near the floor. In the Somerset basin the bed maintains a thickness usually not over

3 feet, but rarely reaching 3 feet 6 inches of bright coal. It is worked in a 3 foot 7 inch top bench, separated by 1 inch of shale from a 2-inch bottom bench at Geiger station, where it furnishes a bright friable columnar coal, yielding fixed carbon, 71.656 per cent; volatile hydrocarbon, 19.144 per cent; sulphur, 0.464 per cent; ash, 8.220 per cent. In the west-central part of the county the seam averages about 2 feet 11 inches. The bed is thin about Garrett, and is in poor condition farther down Castleman River, where it averages 2 feet in thickness and carries considerable sulphur.

The "Sawmill" bed, 740 feet below the Elk Garden coal, is supposed to represent the Upper Freeport bed in the Potomac basin, where locally it shows 2 feet 3 inches of coal in an upper bench, parted by 6 inches to 1 foot of shale from the 1 foot to 1 foot 6 inches lower bench. This bed is known as the Thomas coal in the western Maryland portion of this basin, where it is a valuable fuel.

Whenever in good condition, especially in northern Somerset County, the Upper Freeport coal is bright, soft, and columnar, and usually easily coked. It offers a large area for future development, though it is generally impaired, particularly in the second basin, by the thin parting and disseminated sulphur.

In the Ligonier basin the two Freeport beds are the most important coals of the Allegheny formation. The upper bed is highly variable, occurring usually as a double, sometimes a triple, and rarely as a single bed, and generally carrying widely fluctuating proportions of sulphur and ash. The bed is reported to be cleanest and least broken by partings, though sometimes less than 2 feet thick, along the Youghiogheny River. South of the latter it dilates locally to a thickness of 9 feet 7 inches, the upper division, 6 feet 9 inches, containing 14 interbedded coal seams. Generally, however, in this region the bed runs about 3 feet 6 inches to 4 feet 6 inches, including partings. North of the Youghiogheny River the bed is reported to be double, the top bench being unusually shaly and parted in two layers, 1 foot 7 inches and 3 inches thick, and separated from the lower bench, which is 2 feet 11 inches thick, by 1 foot of clay. The lower bench in this vicinity is prismatic, but is usually injured by clay partings, so that, although locally good, the bed is on an average below the present standard of quality.

Near Indian Creek, in Westmoreland County, the coal is badly parted, presenting 8 inches coal, 1 foot 2 inches clay, 8 inches hard shale, and 1 foot 8 inches bottom coal; but on the Loyalhanna it is said to show a thickness of 3 feet 6 inches to 4 feet in one bench. At Ligonier it measures 5 feet to 7 feet, the upper division being double and separated by 11 inches of clay from the lower division. On Tub Mill Run the upper division is said to be 3 feet 5 inches to 5 feet, with 2 feet of bony coal intercalated, while the lower division, separated by a 9-inch parting, ranges from 2 feet 3 inches to 4 feet 6 inches. The fuel of the upper division is in thin, brilliant layers. That of the lower division is dull and crumbly. In general, throughout the Ligonier basin this bed contains too much sulphur and ash for marketing, without great care in cleaning.

In the Blairsville basin the Upper Freeport bed is double near the Maryland line, where in a good section it shows 2 feet top and 3 feet 6 inches bottom coal beneath a 1 foot 6 inch clay parting. Both benches vary greatly in short distances, becoming dirty under expansion, which at one point is said to reach 17 feet, and cleaner where thin. At Dunbar the section is reported to contain 2 feet coal, 3 feet shale, and 5 feet 8 inches coal, and at Connellsville the measurement is given as 2 feet for the upper division and 6 feet for the lower, the parting being 1 foot in thickness. In the vicinity of Mount Pleasant and north of the Loyalhanna it would seem that the bed may be depended on for 3 feet of good coal, while locally it offers two 3-foot benches separated by 18 inches of parting.

In general the coal appears to be in fair condition along the west slope of Chestnut Ridge, where it measures 2 to 5 feet when single, and locally thickens to 10 feet 6 inches, in two benches 3 and 5 feet thick in restricted areas. It is especially good near the Conemaugh River, where the coal is nearly as good as that of the Pittsburg bed, except in respect to sulphur. In the western portion of Fayette and Westmoreland counties this bed is usually thin and badly broken, though it is mined to a slight extent, with 3 to 4 feet of coal, on Jacobs Creek, and 2 feet 6 inches on Little Sewickley. It merges into a single bed, with a thickness of 3 feet 8 inches to 5 feet, farther north. Along the Allegheny River, in northwestern Westmoreland County, the Upper Freeport is irregular under the Mahoning sandstone, which in places cuts out more or less of the coal, so that the thickness of the bed ranges from 1 to 8 feet, reaching the latter near Tarentum. The coal of the better areas in the northern part of Westmoreland contains about 34 per cent of volatile hydrocarbon, 56 per cent of fixed carbon, with usually a rather large but variable percentage of sulphur.

In the extreme northeastern portion of Allegheny County the Upper Freeport is exposed in a section showing about 3 feet 2 inches to 4 feet of pyritous coal. Below Tarentum, on the Allegheny River, the bed exhibits a very remarkable local dilation to the thickness of 10 feet or more. Here it is somewhat variable; but at Hitestown, which may be taken as a typical locality, it includes two upper 3-foot benches, separated by 7 inches of bone and shale from a bottom bench 1 foot 3 inches thick, with very thin partings. Locally the top bench is an impure cannel. Similar sections with rich bituminous coal are seen on Big Deer Creek to the southwest in West Deer Township, while still farther southwest, on Pine Creek, in Shaler Township, the bed shows a thickness of 7 feet 6 inches, of which 6 feet is good coal. Thin exposures in the deep-stream cuttings appear to indicate the presence of a fine body of coal at this horizon extending in a generally northeast-southwest direction beneath the Conemaugh formation through three townships in northern Allegheny County. That such a development would not have any great width is indicated by the thinning of the bed both to the northward and the southward along the anticlinal exposures.

Although the horizon of the Upper Freeport coal extends through most of Beaver County, the bed is extremely variable and irregular, not being commercially workable except in two areas. In South Beaver Township it is 4 feet 6 inches thick, with four shale partings embracing one bench of coal 3 feet in thickness, too sulphurous for other than domestic use. Where thick enough to work the seam has a main bench of 2 feet 6 inches to 3 feet of coal, topped by 6 to 8 inches of shale and shaly coal, underlain by a thin parting and an impure and sulphurous bottom bench. Locally the coal is in good condition, and is worked. South of the Ohio River the coal is usually so broken by partings as rarely to afford 3 feet of coal in a single bench. The average thickness of the seam in twenty sections in Beaver County is 3 feet 8 inches.

The coal appears to reach its northwest limit in Butler County, whence it deteriorates rapidly to the northwest over a line extending from Brady's Bend in a southwest direction. It measures 4 feet at Butler and is of workable thickness where exposed to the eastward, reaching 6 feet in places, but carrying a shaly parting and some dirty coal. Usually, however, it contains less than 4 feet of coal, which is apt to be more or less sulphurous. In the central portion of the county it is only locally workable, and in the western half it rarely exceeds 2 feet in thickness. Southeastward from Brady's Bend the seam is usually in fair condition and extends, generally in workable thickness, toward the Maryland line. In Beaver County the horizon of this bed is represented by the coals locally known as the "5-foot" and the "4-foot" beds, lying 130 to 140 feet above the Upper Kittanning coal. The seam overlies but a small area in the southern townships of the county. It exceeds 6 feet in thickness at several points in Little Beaver Township, while its best development is in Big Beaver Township, where it presents two 3-foot benches of shaly pyritous coal separated by 2 inches of shale.

At Sharpsburg, a few miles below Pittsburg, the horizon of the Upper Freeport coal is 80 to 100 feet below the river level and 660 feet below the Pittsburg coal. It is not exposed in Washington, Greene, or southern Allegheny counties.

In the Broadtop coal field the Kelly coal is generally recognized as the representative of the Upper Freeport, though there is some difference of opinion as to this correlation. This bed is extremely variable though very valuable, being second in importance and excellence in the coal field. In the southern part of the field, on Long Run, in Bedford County, it lies 30 feet below the supposed Mahoning sandstone and about 120 feet above the Barnett coal, with an average thickness of about 4 feet 6 inches in three benches. At one point in the Cunard basin on Sixmile Run it measures nearly 14 feet in thickness, including 11 feet 6 inches of coal. The coal of this seam, which is largely exhausted in this district, is semibituminous, yielding 17.910 per cent volatile hydrocarbon, 75.239 per cent fixed carbon, 0.656 per cent sulphur, 5.665 per cent ash.

The thickness of this bed varies greatly even within a short distance, and in Huntingdon County, a few miles to the northward, it is not workable, the thickness being 8 to 12 inches, while at a number of points it has not been recognized.

The "E" coal of the Ralston-McIntire basin of Lycoming County, which is considered by the State geologists as the equivalent of the Upper Freeport coal, is a valuable bed, ranging in thickness from 2 feet 6 inches to 7 feet and averaging 4 feet 6 inches, with a bone top and a 3-inch parting 1 foot above the base. Usually it yields about 4 feet of clean coal, though locally furnishing nearly 7 feet of clean coal, and in places decreasing to 3 feet. In the Ralston basin it ranges from 2 feet 8 inches to 3 feet in thickness. The coal is a deep black, clean, semibituminous fuel, containing approximately 17 per cent volatile hydrocarbon, 71 to 78 per cent fixed carbon, 0.74 per cent sulphur, 6.702 per cent ash, the fuel ratio being 4.113.

Of the areas of the Upper Freeport coal which remain undeveloped the largest and most promising are embraced in the lower Allegheny Valley and the southern counties of the State. A considerable area of coal of better quality is available in southern Clearfield and eastern Cambria counties, although in the portion embracing the vicinity of Houtzdale it is much damaged by the removal of the Lower Freeport coal, which lies in this district about 30 feet below. Analyses of this coal are given on page 184.

CONEMAUGH FORMATION.

GENERAL CHARACTERS AND THICKNESS OF THE FORMATION.

The division of the Coal Measures next overlying the Allegheny formation in the bituminous coal fields of Pennsylvania is the Conemaugh formation, more commonly known in this State as the "Lower Barren" Measures (XIV). Its discrimination and limits are largely dictated by convenience and the relative paucity of workable coal rather than by any historical or lithological unity of the beds. It lies between the Upper Freeport coal, the topmost bed of the Allegheny formation, and the floor of the Pittsburg coal, the basal stratum of the Monongahela formation (XV). The lower part of the formation, beginning with the Mahoning sandstone or its equivalent, is prevailingly arenaceous; the upper part contains a very large percentage of reddish and greenish shales in the southwestern corner of the State, and is more or less arenaceous toward the Allegheny escarpment. The Conemaugh contains a number of thin limestones and in Pennsylvania about six recognized coal horizons.

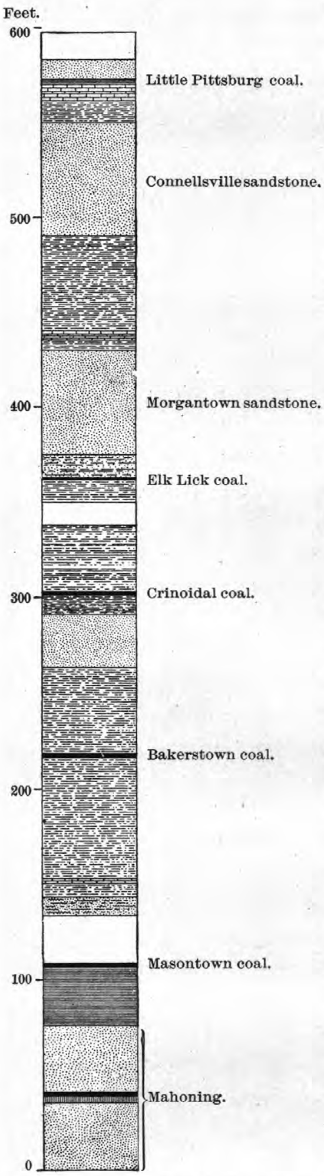

FIG. 23.—Section of the Conemaugh formation on Dunbar Creek, Fayette County (after I. C. White).

COALS OF THE CONEMAUGH.

The coals of the formation are notorious for their variability in thickness. For, while several of the seams are persistent and may be traced over large areas, all are extremely irregular, sometimes of workable thickness on one farm and thin or absent on the next farm. When thick enough for mining they usually contain so large a proportion of earthy material as to unfit them for commercial exploitation; so that, outside of the Berlin basin, this formation does not at present, and perhaps will not for a long time to come, furnish any appreciable amount of fuel for the market.

In the following notes brief mention is made of the principal developments of the seams that either are more persistent or are of some local economic importance. The measurements quoted are generally maximum, and the extreme irregularity and uncertainty of the beds should be kept in view in forming any conception of the coal resources of this field.

The Gallitzin, the lowest persistent coal horizon of the Conemaugh formation, lies within the Mahoning sandstone, the basal member of the formation. In Cambria County, including its type locality, it occasionally exceeds 2 feet in thickness, though often it measures only a few inches. Near Utahville, in this county, it was formerly worked, the thickness being from 2 to 3 feet. The horizon of this coal is supposed to be represented in the Broad Top coal field by the "Spear" bed, which locally exhibits a somewhat lenticular development of 1 to 10 feet of good domestic coal. The Gallitzin horizon is said to be persistent in Indiana County, with a local thickening to 3 feet in the Ligonier basin. It is correlated also with the "Millerstown" bed, 3 to 5 feet thick in northern Butler, and is reported to be equivalent to the Brush Creek coal, 6 inches to 3 feet thick in portions of southern Butler County. In both areas the coal, though too poor for the market, is worked in the absence of better beds. Although the Brush Creek coal is patchy and variable in Lawrence County, it is pure at a number of points, and was once used in a raw state in the Lawrence furnace, the coal being low in sulphur and ash, with about 40 per cent of volatile hydrocarbon and 55 per cent of fixed carbon. At one point in Beaver County it is said to show 5 feet of impure cannel coal.

The Masontown coal of West Virginia appears to be persistent, with 6 inches to 1 foot of coal, often but black shale, in western Pennsylvania, wheie it is in some places said to have been identified as the "Brush Creek" coal.

The Berlin basin is remarkable both for the number and the exceptional purity of the coals in the Conemaugh formation, which are there mined somewhat extensively for shipment. Of these the lowest in the formation is the "Philson" bed, which is worked near Pine Hill, with a thickness of over 4 feet of fine domestic coal. It is probably the representative of the "third" coal in the Wellersburg basin, 3 feet in thickness. The bed regarded as belonging to the same horizon in Indiana County is there the "second" coal above the Upper Freeport coal and 50 feet above the Gallitzin coal. It is mined with a thickness of 4 feet at Armagh, though generally thin and worthless in this region. In Fayette County it is said to contain 1 to 6 feet of rather impure coal, 40 to 90 feet above the Upper Freeport coal. The Coleman bed, the "second" coal above the Mahoning sandstone in the Berlin basin, is workable with about 3 feet of coal about Pine Hill, and on one farm it increases to 6 feet in thickness, but is less pure Near Armagh, in Indiana County, a bed supposed to represent the Coleman is 3 feet thick, and dirty.

The third relatively persistent coal of the Conemaugh is named from Bakerstown, Allegheny County, near which it has long been worked with 3 feet of valuable coal. The Bakerstown coal not infrequently reaches a thickness of 2 feet 8 inches in the county, and at one point it is 3 feet thick, with 6 inches of cannel coal. In Beaver it swells at one point to 6 feet of cannel and bituminous coal. This coal, which is 70 to 90 feet below the Crinoidal limestone and 405 feet below the Pittsburg coal in Allegheny County, is correlated with the "Price" coal, 385 feet below the Pittsburg coal in the Berlin basin The Price coal, 60 feet above the Coleman bed, is one of the most important in the latter basin, occuring in 5 benches and yielding about 4 feet of soft, friable columnar coal, which contains 68.944 per cent fixed carbon, 1.176 per cent sulphur, and 8.680 per cent ash. The Price coal underlies a large area in the Berlin basin, and will continue to furnish merchantable coal for a long time to come.

The most valuable coal of the Berlin basin is the Berlin coal, 280 feet below the Pittsburg coal. This bed, which is extensively worked, is fairly reliable. It has a thickness ranging from 3 feet 2 inches to 4 feet 9 inches, and averages 4 feet of rich, lustrous, friable, prismatic coal, containing 0.744 per cent sulphur and 8.390 per cent of ash. A coal supposed to be at the horizon of the Berlin coal in the Wellersburg basin shows two benches, one with 2 feet 6 inches, the other with 2 feet of coal, separated by a 6-inch to 2 feet 6 inch parting.[a]

The Elk Lick coal, another seam of reported wide extent, though of variable character, lies just beneath the Morgantown sandstone. It sometimes attains a thickness of 4 feet in Somerset County. Near Wharton furnace, in Fayette County, and at Ligonier, in Westmoreland, it was formerly mined, ranging from 18 inches to 4 feet, though it does not usually reach a thickness of 2 feet in these counties. A patchy thickness of the seam is found near the head of Hites Run, in Allegheny County, where it furnishes 3 feet to 3 feet 6 inches of good coal. Generally the bed does not exceed 2 feet 8 inches in this county.

The "Little Pittsburg" coal is the highest fairly persistent coal seam in the formation in Pennsylvania. This bed has a wide extent in Greene, Washington, Fayette, and Westmoreland counties as well as in Somerset County. It rarely reaches a thickness of 2 feet, though in exceptional instances it increases to 4 feet. When in workable thickness, its proximity to the thicker coal above generally prevents its exploitation, even when it is sufficiently clean for domestic use. In Allegheny County this coal seldom exceeds 18 inches in thickness, and in Indiana County it ranges at best from 1 foot to 16 inches.

The "Painter" bed, the highest coal of the Conemaugh formation, ranges in the northern portion of the Ligonier basin from 7 inches to 6 feet in thickness and has been largely worked locally near Nineveh.

Analysis of the coals of the Conemaugh formation are given in the table on p. 185.

Although the coals of this formation are exposed in a wide territory and are of workable thickness at a large number of localities, it is not likely that, outside of the Berlin basin, they will contribute to the output of merchantable coal until the better areas of the Freeport and the Upper and Lower Kittanning coals of the Allegheny formation have been exhausted. As to composition, they are more nearly

[a] A coal, correlated with the Little Clarksburg bed, is known as the "Six-foot" bed in the Wellers burg basin of Somerset County.

comparable to the Clarion and Brookville coals; and it is probable that where the conditions of geographical position are equal, the eastern areas of the latter coals will be preferred in exploitation on account of the generally greater regularity and stability of the beds.

MONONGAHELA OR UPPER PRODUCTIVE FORMATION (NO. XV).

GENERAL CHARACTERS AND THICKNESS OF THE FORMATION.

This series extends from the bottom of the Pittsburg coal to the top of the Waynesburg coal, having an average thickness of about 360 feet. The series is confined to the southwestern corner of the State, occupying the whole of Greene and Washington counties, a considerable portion of Allegheny, Fayette, and Westmoreland counties, and small isolated areas in Somerset and Indiana counties.

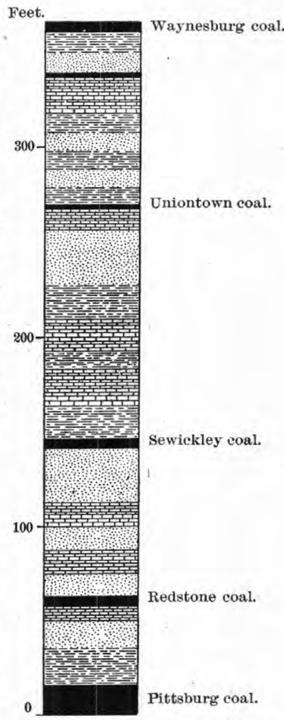

FIG. 24.—Section of the Monongahela formation in Fayette County (after Stevenson).

Aside from the great Pittsburg bed, which forms the base, the series contains a number of coals that locally are of workable proportions. At present these receive little or no attention on account of their comparative low values, but when the Pittsburg bed is exhausted they will doubtless be called into requisition to meet the constantly increasing demand for fuel.

COALS OF THE MONONGAHELA.

PITTSBURG COAL.

This is the most uniform in quality and thickness and, for a given area, the most valuable coal bed in the bituminous coal field of Pennsylvania. Since it occurs at the base of the Monongahela formation, it coincides in extent with that series in Pennsylvania, as shown on the accompanying map. It occupies an area in this State about 50 miles in length by 50 miles in breadth, with an average thickness of presumably about 6 feet. On this basis it is estimated that the Pittsburg coal bed originally contained more than 10,000,000,000 tons of available coal, and even after sixty years of mining it is probable that the available coal is not reduced below the figures given above.[a]

In quality the coal of the Pittsburg bed is for many purposes perhaps equal if not superior to the best bituminous coal found elsewhere in the Appalachian field or in the world. It is an excellent domestic and steam fuel, its calorific value, as determined by Prof. N. W. Lord,

[a] Dr. H. M. Chance; Sixteenth Ann. Rept. U. S. Geol. Survey, Part IV, p. 183.

being in B. T. U. 13,557. It mines in large blocks, which withstand the rough usage incident to long shipments and frequent breaking of bulk, and consequently it is well adapted for export and for the more distant home markets.

It is a high-standard producer of illuminating gas, containing from 36 to 38 per cent of volatile combustible matter in portions of the field. For the manufacture of coke the Pittsburg has few if any equals in the United States.

The average of a large number of analyses of the coal and coke of the Connellsville basin furnishes the following, which may be considered as representing the average composition of coal and the resulting coke from this district:

Average composition of coal and coke from Connellsville basin.

	Coal.	Coke.
	Per cent.	*Per cent.*
Moisture	....	0.184
Volatile matter	31.04	.552
Fixed carbon	61.97	88.726
Ash	5.77	9.993
Sulphur	1.22	.533
Phosphorus	....	.010

The average of a large number of analyses for ash in the coke, covering the delivery of 150,000 tons at the Edgar Thompson Steel Works, gives 9.75 per cent. This may therefore be regarded as the average ash in good Connellsville coke.

Owing to the folding which the strata in the eastern part of the coal field have undergone and the subsequent erosion of the higher beds from the anticlines, the members of this series occupy a number of isolated basins. The easternmost and smallest of these is the Salisbury basin in Somerset County, having an area of about 3,600 acres of workable coal. In this basin the bed does not show the regular partings which characterize it farther west. In many sections they are entirely absent and in others they are scattered irregularly through the bed. In thickness the coal ranges from 8 or 9 feet in the vicinity of Salisbury to about 6 feet in the northern end of the basin. The character of the coal is shown by analysis 68, page 185, which is the average of 4 analyses of samples from different parts of the basin.

In the next syncline to the west a small area of about 2,000 acres is all that remains of this coal bed. It is from 7 to 8 feet in thickness where it caps the hills in the Ligonier Valley in Westmoreland County. Its character in this basin is shown by analysis 69, page 185, which is an average of 2 samples collected at opposite ends of the field. This shows the coal at its best. Other analyses give as much as 3 per cent of sulphur and from 6 to 9 per cent of ash.

The first great area of Pittsburg coal occupies the synclinal trough west of Chestnut Ridge. This is the well-known Connellsville basin, where the reputation of the Pittsburg coal as a coke maker has been most thoroughly established. The extreme length of this basin is about 60 miles, its width varies from 2 to 6 miles, and its area is estimated to be not less that 150 square miles.

Very little coke is manufactured in the northern end of the basin, the productive territory, from the coke makers' standpoint, lying southwest of the main line of the Pennsylvania Railroad at Latrobe and Loyalhanna.

Throughout the basin the coal bed consists of two divisions, separated by a clay parting from 6 to 12 inches in thickness. The roof division varies from a few inches to 5 feet in thickness, but the coal in this part is interstratified with shale bands, and it is regarded as worthless and not removed in mining operations. The lower bench varies from 7 to 9 feet in thickness. In some localities it is entirely free from shale impurities, but generally there is a thin "bearing-in slate" about 18 inches from the floor, and a few other shale partings come in irregularly.

The coal is soft and easily mined. It breaks up into fine particles, and is thus in the best condition for thorough coking. The composition of standard Connellsville coal, according to Mr. John Fulton, is shown by analysis 70, p. 185. The average of 10 analyses from as many mines of the H. C. Frick Coke Company in the vicinity of Connellsville is given in analysis 71.

The coke from the Connellsville region has a silvery luster, cellular structure, and a sharp metallic ring. It is tenacious, comparatively free from impurities, and capable of bearing a heavy burden in the blast furnace. One of its essential qualities is its low percentage of phosphorus. A. S. McCreath[a] cites 5 analyses in which the phosphorus ranged from 0.0130 to 0.0247 per cent.

The development of this basin during the first decade has been extremely rapid. From a total of 70 coke ovens in operation in 1860 the number has grown to over 21,000 ovens at the present time.

The Greensburg basin lies west of the northern end of the Connellsville basin. It has a width of about 3 miles in its widest part and a length of 12 miles, extending from a point a little southwest of Greensburg northeasterly nearly to the Conemaugh River.

The roof division of the coal is from 4 inches to 2 feet in thickness and has no commercial value. The main bench of coal is from 6 to 8

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[a] Trans. Am. Inst. Min. Eng., Vol. VIII, p. 75.

feet in thickness, and it is separated from the roof division by a clay parting, which varies from 6 to 18 inches in thickness.

Coke is produced in this basin, but the coal is not so good for this purpose as it is in the Connellsville basin. In physical and chemical properties it is intermediate between the coking coal on the east and the rich gas coal on the west. It is harder than either, and forms a good steam or domestic fuel.

The Irwin gas-coal basin is geologically a part of the great Greene-Washington coal field, but the triangular tract lying north of the Youghiogheny River is treated separately on account of the peculiar character of the coal. Within this basin the bed is everywhere thick and contains valuable coal.

Sections measured in 7 townships show the upper division to be worthless, and to vary in thickness from 10 inches to 3 feet. The usual clay parting separates this from the bottom bench, which ranges in thickness from 6 feet to 8 feet 6 inches in thickness. The coal of the upper bench (about 4 feet in thickness) is hard and firm and is a rich gas coal that is highly prized for its general excellence and its high illuminating power. Its composition in this district varies considerably, as shown by the analyses given in the table. Where the coal is in its best development as a gas producer its average composition is represented by analysis 72. In other parts of the field it runs lower in volatile matter and higher in sulphur and ash, as shown by analysis 73, which is an average from 7 carefully collected samples in various parts of the field.

The main body of the coal lies in the southwestern corner of the State, embracing the whole of Greene and Washington counties, and extending east into Fayette County and north in Allegheny County.

The coal is being mined extensively on the northern and eastern margin of this field, but in the central part, embracing an area of at least 1,000 square miles, it has not been touched. True, in most of this region it lies deep below the surface, but it is only a question of time when it will be reached by shafts, even if they have to penetrate to the level of the sea.

Although the Pittsburg coal is everywhere a coking coal, it generally had been supposed that in the Greene and Washington field the coke produced from it could not compete in open market with Connellsville coke. This is undoubtedly true of the major portion of the field, but there are notable exceptions which promise to enlarge the area of coke production to a considerable extent.

For a number of years the coal from the Vesta mines on Monongahela River in Washington County has been successfully coked, but this is an isolated case, being the only one on the river. On Washington Run coke is being manufactured and also on Redstone Creek, and within the past few years an extensive coking field has been developed in the vicinity of New Salem and Masontown, in Fayette County.

From these various developments it appears that there is an area of valuable coking coal along the eastern margin of this great field from the Youghiogheny River southward to the State line.

East of the Monongahela River the coal maintains its customary character and thickness. The top coal, which is generally worthless, varies in thickness from 4 inches to 6 feet. Below this is the usual clay parting, which ranges from a few inches to 1 foot in thickness. The bottom bench of coal is remarkably regular in this region, ranging from 6 to 9 feet in thickness. Its composition in this district is fairly well represented by analyses 74 and 75, which were made from samples obtained at Monongahela City and Coal Center, Washington County.

Along the northern border of the field the coal varies greatly in section, growing gradually thinner and more slaty toward the western border of the State. The main clay parting is generally only a few inches in thickness; hence the bed is more nearly a unit than in the eastern fields, but it is broken by many shale partings.

Little is known regarding the character of the coal or the section of its bed in the deeper parts of the basin in Greene and Washington counties. From analysis 76, which shows its composition on Dunkard Creek in Greene County, it seems at least as though the eastern part of the basin carries valuable coal, and the drill records attest its presence in various parts of the basin with about the same aggregate thickness that it holds in outcrop on the edges of the field.

The commercial development of this coal about the margin of the field is extensive. Slack-water navigation on Monongahela River has led to the development of numerous and extensive mines on that stream as far up as Brownsville. Railroad mines are abundant along Youghiogheny River and up the many small streams which flow northward through northern Washington and southern Allegheny counties.

REDSTONE COAL.

This coal bed occurs from 40 to 60 feet above the Pittsburg coal, and, owing to this close proximity, it is doubtful if it can be worked after the removal of the great bed so close below it.

In its best development it ranges from 3 to 4 feet in thickness, but over much of the territory in which it is due it is too thin to mine under existing conditions. In the Salisbury basin, in Somerset County, it is 4 feet in thickness, but it is slaty and of little value. In several townships of Allegheny, Westmoreland, and Fayette counties it attains its maximum thickness, and it has been mined for local use, but, on the whole, it does not promise much for future development.

SEWICKLEY COAL.

This bed lies about 110 feet above the Pittsburg coal. It is widely persistent, but it is economically valuable over a comparatively small area. Its best development is found along the Monongahela River in Greene County, where it is from 5 to 6 feet in thickness, with 2 to 3 inches of shale near the middle of the bed. It is an open-burning coal that is much prized as a domestic fuel. Toward the north it decreases in thickness, measuring at Brownsville 4 feet 4 inches, with 2 inches of clay in the bottom part of the bed. It shows on Chartiers Creek, in Washington County, but usually as a bituminous shale only.

In Fayette County it is present in workable thickness in several townships in the southern part of the county, but toward the north it becomes thin, and disappears in Westmoreland County. It is scarcely known in the Ligonier basin, but is 2 feet in thickness in the Salisbury basin in Somerset County.

This coal has been mined quite extensively for local use at Mapletown, Greene County, where its composition is shown by analysis 77. Farther south it improves in composition, as shown by analysis 78, which is from a sample collected in the valley of Dunkard Creek, near the West Virginia line.

UNIONTOWN COAL.

The Uniontown coal lies from 80 to 100 feet below the Waynesburg coal. It is a persistent bed and has been noticed as far east as the Salisbury basin in Somerset County, where it is 3 feet or more in thickness and holds a slate parting. It is important as a fuel only in Fayette and Washington counties, where it seldom exceeds 3 feet in thickness. It acquired its name from Uniontown, Fayette County, where it is exposed in two benches 1 foot 5 inches thick with 4 inches of clay between them.

WAYNESBURG COAL.

This bed is regarded as the topmost member of the Monongahela series, and its outcrop corresponds with the top of this formation, as shown on geological maps of this region, except in many places in eastern Fayette and Westmoreland counties, where the coal appears to be lacking.

The Waynesburg coal is almost universally a double bed, being divided by a shale parting which generally ranges from 1 foot to 2 feet 6 inches in thickness. It yields a hard block coal which is frequently worthless from the high percentage of ash and sulphur. Its average composition is about 50 per cent fixed carbon, from 32 to 36 per cent volatile matter, 1.3 to 3 per cent sulphur, and 11 to 13.5 per cent ash.

The region of best development of the Waynesburg coal includes

Dunkard, Greene, Monongahela, Cumberland, Jefferson, and Perry townships of Greene County; German, Brownsville, and Redstone townships of Fayette County, and East Bethlehem and Pike Run townships of Washington County. Within this central area the best coal lies in the northeastern part of Greene County, where the following section represents the average of 10 separate measurements:

Average section in Greene County, Pennsylvania.

	Ft.	in.
Coal	1	4
Clay	0	5
Coal	2	1
Clay	0	9
Coal	2	2

Generally speaking, throughout this central area the bed has a thickness of from 5 to 10 feet, of which a fourth, a third, or sometimes a half consists of clay partings.

This coal is also present in the headwaters of Wheeling Creek in Washington County, but it is thin in this direction. In Rostraver and South Huntingdon townships of Westmoreland County the coal is excellent, but the bed has a thickness of only 3 feet.

DUNKARD FORMATION.

GENERAL CHARACTERS AND THICKNESS OF THE FORMATION.

This series is generally regarded as barren of workable coal beds, but the time may come when even its poor coals will be in demand. The coal beds which have been recognized and named, from below upward, are: Waynesburg "A" coal, the Little Washington and Washington coals, the Jollytown, Dunkard, and Nineveh beds. The only one of these beds which attains sufficient thickness to be mentioned here is the Washington coal. This is always a multiple bed, being separated into two or three layers by divisions of shale. Sometimes these partings are numerous and the entire thickness of the bed is 8 or 10 feet, but, in all cases, the only pure or merchantable coal is the bottom portion, which seldom exceeds 2 feet 6 inches or 3 feet.

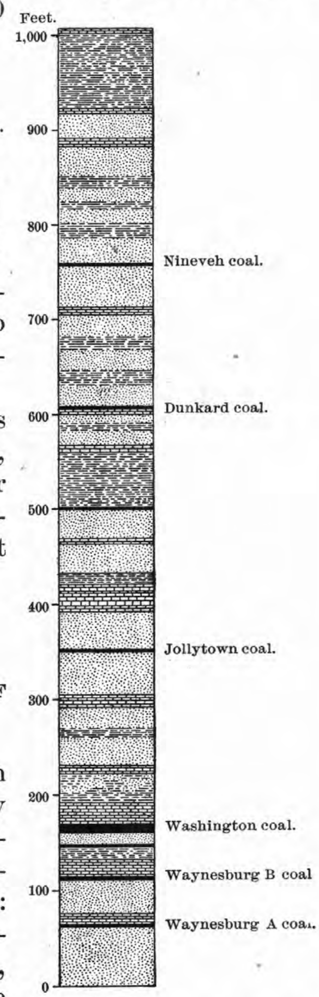

FIG. 25.—Section of the Dunkard formation in Greene County (after Stevenson).

This bed is generally thin in Greene County, but increases in thickness and complexity in Washington County. Its condition in the latter county is well illustrated by the following section from Canton Township:

Section in Canton Township, Washington County, Pa.

	Ft.	in.
Coal	0	3
Clay	0	8
Bituminous shale	0	10
Clay	1	3
Coal	0	5
Clay	0	1
Coal	0	2
Clay	0	2
Coal	0	3
Clay	0	3
Coal	2	9
	7	1

CHARACTER OF THE COALS.

As was noted in the discussion of the distribution of the coals, the character and consequently the uses of the fuel from a given coal horizon vary widely in different portions of the field. The most important of these variations are in accordance with the general principle of the progressive devolatilization of the fuel in passing from the western border of the State toward the anthracite region. The coal of the Bernice basin, Sullivan County, which is, on chemical grounds, included in the anthracite regions, though physically it is to be grouped with the soft coals, has a fuel ratio of 10.3. The fuel ratio of the semianthracite from the Barclay basin in Bradford County is 4.1. The same bed has a fuel ratio of 3.9 in the Blossburg basin, in Tioga County, and 3.5 at Gaines, near the Potter County boundary. The Barnett semibituminous coal has a fuel ratio of about 4.3 in the Broadtop field, and the fuel ratio of its supposed representative, the Lower Kittanning, on the Allegheny Front, in Cambria County, is about 3.5. Although there are certain important exceptions, largely local, the proportion of volatile combustible matter in the coal increases progressively in passing toward the western border of the State, where the fuel ratio is about 1.5.

The quality of the coals from the more important of the beds developed in the bituminous regions of the State is indicated by the results of the chemical analysis quoted from the large number published in the reports of the Second Geological Survey of the State. In many cases the composition varies greatly between nearby localities. Those selected are regarded as generally typical. It is not practicable here to report as large a number of analyses as is needed to do justice to the region, and the reader is therefore referred to the special report of the chemists of the late State survey.[a]

[a] Repts. M, MM, and M3.

Analyses of coals from Pennsylvania bituminous coal fields.

No.	Locality or township.	County.	Name of coal.	Volatile combustible matter.	Fixed carbon.	Sulphur.	Ash.	Water.	Fuel ratio.
1	Pulaski	Mercer	Sharon	35.300	53.875	0.675	6.360	3.790	1.53
2	Forkston	Wyoming	Mehoopany (upper bench)	12.410	75.611	.574	10.745	.930	6.09
3	....do	....do	Mehoopany (lower bench)	13.060	71.679	.581	13.870	.810	5.49
4	Shippen	Cameron	Lower Alton (top bench)	36.895	52.593	2.037	7.265	1.210	1.42
5	....do	....do	Lower Alton (bottom bench)	28.990	35.588	.977	33.385	1.060	1.28
6	Jay	Elk	Middle Alton	32.170	59.323	2.067	4.670	1.770	1.84
7	Shippen	Cameron	Upper Alton	33.090	53.006	1.874	10.900	1.130	1.60
8	Morris Run	Tioga	Bloss	18.570	72.097	.583	7.630	1.120	3.88
9	Powelton	Huntingdon	Fulton (Cook) (top)	21.082	72.893	4.145	1.312	.568	3.45
10	....do	....do	Fulton (Cook) (middle)	20.776	69.403	8.635	.752	.434	3.34
11	....do	....do	Fulton (Cook) (bottom)	19.199	73.785	5.830	.670	.516	3.84
12	Woodcock mine	Blair	Brookville	26.290	66.133	.567	5.750	1.260	2.51
13	Conemaugh	Cambria	....do	17.930	75.508	.567	4.525	1.470	4.21
14	Brookville	Jefferson	....do	39.615	48.532	1.238	9.265	1.350	1.22
15	Slabtown	Armstrong	....do	35.715	51.049	.936	11.560	.740	1.43
16	Rough Run	....do	Clarion	42.650	48.661	1.644	6.035	1.010	1.14
17	Bells Mills	Indiana	....do	27.880	61.920	3.610	6.030	.560	2.22
18	Shippen	Cameron	Clermont	32.220	53.904	3.481	9.475	.920	1.67
19	Benzinger	Elk	....do	37.890	52.657	.838	7.745	.870	1.39
20	Arnot	Tioga	Seymour	21.586	71.574	.907	4.753	1.180	3.31
21	Coal Hill	Center	Lower Kittanning	23.554	65.778	.787	9.165	.716	2.78
22	Houtzdale	Clearfield	....do	21.360	72.284	.435	3.510	.670	3.47
23	Bennington	Blair	....do	26.340	64.373	1.792	6.585	.910	2.44
24	Powelton	Center	Lower Kittanning (lower bench)	22.600	68.709	2.691	5.400	.600	3.04
25	Ben Creek	Cambria	....do	17.935	76.503	.602	4.345	.615	4.26
26	Cherrytree	....do	Lower Kittanning	25.185	66.797	.568	6.190	1.260	2.65
27	Listonville	Somerset	....do	26.000	55.683	2.167	15.550	.600	2.14
28	Piney	Clarion	....do	41.355	49.930	2.070	5.175	1.470	1.21
29	Kittanning	Armstrong	....do	40.855	51.654	1.366	5.135	.950	1.26

Analyses of coals from Pennsylvania bituminous coal fields—Continued.

No.	Locality or township.	County.	Name of coal.	Volatile combustible matter.	Fixed carbon.	Sulphur.	Ash.	Water.	Fuel ratio.
30	Mount Hope	Cameron	Lower Kittanning	34.395	60.195	.865	3.555	.990	1.75
31	Fox	Elk	Dagus	38.455	53.190	1.975	5.300	1.080	1.38
32	Sixmile Run	Bedford	Barnett	18.015	78.078	.892	2.445	.570	4.33
33	Osceola	Clearfield	Upper Kittanning	24.450	67.045	1.320	5.945	1.240	2.74
34	Putneyville	Armstrong	do	32.665	52.306	1.044	13.345	.640	1.60
35	Redbank	do	Upper Kittanning (middle layer cannel)	37.820	53.132	.678	6.750	1.610	1.40
36	Fairmount	Clarion	Upper Kittanning (cannel)	32.565	49.955	1.960	13.145	2.375	1.53
37	Johnstown	Cambria	Upper Kittanning	17.180	73.424	1.408	6.848	1.140	4.27
38	Kimmels	Somerset	do	15.415	70.632	1.748	11.605	.600	4.58
39	Lancaster	Butler	Darlington	43.250	49.716	2.109	3.470	1.455	1.14
40	Shenango	Lawrence	do	41.210	54.163	.587	1.940	2.100	1.31
41	Darlington	Beaver	Darlington (cannel)	48.015	38.241	.599	11.985	1.160	.79
42	Greene	do	Darlington	38.620	56.333	.717	2.560	1.770	1.45
43	Garrett	Somerset	Lower Freeport	17.135	66.679	.676	14.490	1.026	3.89
44	Philipsburg	Clearfield	Lower Freeport (lower bench)	24.090	71.689	.571	3.10	.55	2.97
45	do	do	Lower Freeport (upper bench)	25.190	71.013	.587	2.65	.56	2.819
46	Houtzdale	do	Lower Freeport	22.720	71.018	.543	3.777	1.942	3.12
47	Cherry Tree	Cambria	do	24.635	72.436	.559	1.570	.800	2.93
48	Fairmount	Clarion	do	40.565	53.980	1.490	2.645	1.320	1.33
49	Winslow	Jefferson	do	30.800	62.524	.776	4.800	1.100	2.03
50	Young	do	do	33.150	58.405	1.295	6.100	1.050	1.76
51	Pine Creek Furnace	Armstrong	do	34.185	58.301	.989	4.705	1.820	1.70
52	Jacksonville	Indiana	do	28.505	55.380	.700	14.405	1.010	1.94
53	Sandy Run	Bedford	Kelly	16.015	76.720	1.230	4.960	.575	4.79
54	Houtzdale	Clearfield	Upper Freeport	20.640	74.023	.507	4.020	.810	3.58
55	Bennington	Blair	do	26.400	65.586	2.274	4.780	.960	2.48
56	Lilly	Cambria	do	22.250	70.518	1.459	5.058	.715	3.16
57	Cherry Tree	do	do	24.630	68.333	1.227	4.930	.880	2.77
58	Blairsville	Indiana	do	27.800	67.537	.718	3.175	.770	2.42

Analyses of coals from Pennsylvania bituminous coal fields—Continued.

No.	Locality or township.	County.	Name of coal.	Volatile combustible matter.	Fixed carbon.	Sulphur.	Ash.	Water.	Fuel ratio.
59	Loyalhanna	Westmoreland	Upper Freeport	34.100	56.088	3.932	4.990	.890	1.64
60	Stewart	Fayette	....do	27.255	61.179	2.031	8.085	.870	2.24
61	Somerset	Somerset	....do	16.885	66.055	.585	15.615	.860	3.91
62	Porter	Clarion	....do	35.320	54.448	.672	8.040	1.520	1.54
63	Hookstown	Beaver	....do	39.520	54.691	1.249	2.460	2.080	1.38
64	Perry	Lawrence	Brush Creek	39.265	55.828	.727	2.240	1.940	1.42
65	Berlin	Somerset	Price (upper bench)	20.330	68.944	1.176	8.680	.870	3.39
66	Pine Hill Run	....do	Berlin	22.760	67.467	.803	7.345	1.625	2.96
67	Salisbury basin	....do	Pittsburg	21.110	69.345	.884	7.216	1.445	3.28
68	Ligonier	Westmoreland	Pittsburg	23.691	64.292	803	9.775	1.435	2.71
69	Connellsville basin	Fayette and Westmoreland.	....do	31.790	57.790	.790	7.160	1.260	1.81
70	....do	Fayette	....do	31.040	61.970	1.220	5.770	....	1.99
71	Irwin basin	Westmoreland	....do	38.105	54.383	.792	5.440	1.280	1.43
72	....do	....do	....do	34.309	56.950	1.076	6.412	1.223	1.63
73	Monongahela City	Washington	....do	35.830	58.154	.761	4.075	1.180	1.62
74	Coal Center	....do	....do	35.350	55.010	.895	7.745	1.000	1.55
75	Dunkard Creek	Greene	....do	38.390	52.649	1.941	6.120	.900	1.37
76	Mapletown	....do	Sewickley	32.220	53.410	1.834	11.242	1.294	1.03
77	Dunkard Creek	....do	....do	35.400	56.818	1.152	4.840	1.790	1.60

The utilization of the coals in the various industries is, however, perhaps more largely dependent on geographical position combined with physical structure and composition, which is regional, than upon mere fuel ratios. Such variation, indicated to some extent in the table, has already been more fully shown in discussing the distribution of the coals. By referring to the latter it appears that the Sharon coal, which is a block coal with alternating layers of mineral charcoal and pitchy coal, strong, free from sulphur, and valuable for furnace use near the Ohio line, becomes dirty, sulphurous, patchy, and of little value to the eastward in the bituminous areas, although its horizon is represented by the Upper Lykens coals in the southern anthracite coal fields, and by some of the most important beds of the Southern Appalachian region.

The coals of the Mercer group, dirty and of little account to the westward, are locally exceptionally free from sulphur toward the northeastward, where the group is probably represented in Tioga, Lycoming, and Bradford counties by the celebrated Bloss coal, or "B" bed, near Blossburg, very highly appreciated for forge and domestic purposes, and capable of producing 73 to 82 per cent of coke.

The Brookville bed appears to be best developed in Jefferson County and along the Allegheny escarpment. It is serviceable only as a somewhat sulphurous heavy steam coal, utilized for heavy grade work on locomotives in the latter region; but in the Broad Top basin it is cleaner, proving a valuable steam fuel, and has been coked to some extent.

The Lower Kittanning coal, mined to a small extent for steam purposes in the Allegheny Valley region, is a valuable coking coal in portions of southern Elk County, makes a fine, strong coke in northern Clearfield County, and is locally coked with reported percentages of 55 to 80 per cent in eastern Clearfield County, 75 to 80 in eastern Cambria County, and 64 to 70 per cent in Blair County. In the eastern region it is also locally important as a smithing coal. It is a valuable heavy semibituminous steam coal in the Broadtop field. This bed and the Lower Freeport are the two most important of the coals of the broadly extended Allegheny formation.

The Upper Kittanning is of minor value for steam and gas purposes in the western districts, where at some points it carries a thick bed of impure cannel. But it becomes of some importance as a steam and domestic fuel in portions of Clearfield, Cambria, and Somerset counties, and is relatively important, making a good coke, in the snowshoe basin of Center County.

Commercially the Lower Freeport has until recently been the most important coal below the great Pittsburg bed, though its rapid exhaustion is bringing the Lower Kittanning into prominence. This remarkably valuable bed predominates wherever present over the greater portion of a belt about 45 miles in width, extending eastward from eastern Jefferson and northern Indiana counties to the Moshannon Creek, near the Allegheny escarpment. It is particularly important in the Shawmut-Reynoldsville-Punxsutawney basin and the Philipsburg-Houtzdale basin. In the Reynoldsville-Shawmut district this coal is especially valuable for high-grade steam purposes and gas, its geographic position affording it a commercial advantage over the gas coal of the Pittsburg region. Farther south, in the Punxsutawney district, it is very extensively coked also. The coke is bright, silvery, metallic, strong, with hardness and tenacity. It is compact, with cells a very little smaller than the Connellsville coke, and is rather harder than the average Connellsville standard. A sample of the Walston 72-hour coke, analyzed by A. S. McCreath, yielded: fixed carbon, 88.476; moisture, 0.148; ash, 9.731; sulphur, 0.951; phosphorus, 0.008, and volatile matter, 0.692.[a] In the Phillipsburg-Houtzdale basin of eastern Clearfield and northern Cambria counties the seam is known as the Moshannon bed. In this eastern region it is well adapted for steam and coking purposes, making 60 to 80 per cent of coke, while the product of certain mines is said to be valuable for smithing, puddling, and gas making.

The developments of the Upper Freeport coal lie for the most part in a broad zone to the south of the most productive zone of the Lower Freeport, the principal operations being in the Lower Allegheny Valley and Kiskiminitas Valley to the west, and near the Allegheny escarpment to the east. Along the Allegheny River and lower portion of the Kiskiminitas River it is generally too sulphurous for other than steam uses, but about Graceton, in the Blairsville basin, it is successfully coked, the coke percentages varying from 60 to 66 per cent. In Blair and eastern Cambria counties it is coked at several mines, with coke percentages varying from 65 to 75. Farther east, in the Broadtop field, a large portion of the output of the Kelly coal, supposed to represent the Upper Freeport, is shipped as coke, the coke percentage being 62 to 67.

The great Pittsburg coal is adapted to high-grade steam, smithing, and rolling mill use in the small area in Somerset County; to steam and railroad purposes in southern Indiana County. In eastern Westmoreland and Fayette counties it is the source of an enormous coking industry, while farther westward the increased proportion of volatile hydrocarbons makes it especially valuable as a gas coal. Everywhere it is a very high-grade steam coal. The regional variations in the composition of this coal, as well as its coking qualities, are discussed more fully in the remarks on the distribution of the coal. The production of coal and coke from these counties is shown in the table on p. 191. The greater portion of the Connellsville coke is shipped to the furnaces of western Pennsylvania.

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[a] For additional analyses, see Sixteenth Ann. Rept. U. S. Geol. Survey, Pt. IV, p. 285.

DEVELOPMENT OF THE FIELD.

HISTORICAL NOTICE.

Of the Appalachian Paleozoic bituminous coal fields that portion lying in Pennsylvania was first to be commercially developed. The earliest record of coal mining in the Pittsburg region is that supplied by Capt. Thomas Hutchins, who visited Fort Pitt (now Pittsburg) in 1760 and found a coal mine opened on the opposite side of Monongahela River. With the advent of the first steam engine in Pittsburg in 1794 the demand for the new fuel increased, and by 1800 a number of mines were in operation on both sides of Monongahela River, and coal was used quite extensively in salt works, glass factories, and for general purposes.

The first shipment of coal from Pittsburg was made in 1803. As early as 1804 barges were loaded in Clearfield County and floated down to Columbia for sale.

It appears to be uncertain just when coal began to displace the forest supply of fuel, but by 1825 it is reported that about 3,500 tons were used in the vicinity of Pittsburg. This local consumption increased to 464,000 in 1846, in which year 214,000 tons were sent down the Ohio River and 53 steamboats were built for the river trade. To the boats already in use 56 were added the following year.

The Blossburg basin began commercial shipments at about 1842, and the development of the Barclay basin followed not long after. The use of the Sharon block coal in the furnaces of Mercer County is said to have begun in the same decade.

The rapid exploitation of the coals in Cambria County dates practically from the time of the construction of the State Portage and Pennsylvania railways. The remarkable development of the Reynoldsville basin began soon after the construction of the Low Grade division of the Allegheny Valley Railway in 1872. The development of these fields is eclipsed by the wonderful progress made in the size and number of plants and in the increased production of coke in the Connellsville and adjacent basins in the past forty years. From less than 100 ovens in 1860 the field has grown to about 25,000 ovens at the present time.

PRODUCTION.

From a total bituminous coal output of about 1,000,000 tons, as estimated in 1847, the production has increased, with slight fluctuations, to the unprecedented total of 79,318,362 tons in 1900. As reported by the State bureau of mines[a] the increase of coal over the output of 1899 was 6,251,419 tons. The total production of coke in 1900 was 12,185,112 tons, a decrease of 7,808 tons for the year. The records of production

[a] Department of internal affairs, 1900, J. E. Roderick, chief, Official Doc. No. 11, 1901.

and values, by decades, beginning with 1880, are shown in the accompanying table, prepared by Mr. Hazeltine.

Development of the northern Appalachian coal field, by decennial periods.

State.	1880.			1890.			Increase of 1890 over 1880.			
	Production.	Value.	Average price per ton.	Production.	Value.	Average price per ton.	Product.	Per cent.	Value.	Per cent.
Pennsylvania	18, 425, 163	$18, 567, 129	1.00	42, 302, 173	$35, 376, 916	0.84	23, 877, 010	130	$16, 809, 787	91
Ohio	6, 008, 595	7, 719, 667	1.28	11, 494, 506	10, 783, 171	.93	5, 485, 911	91	3, 063, 504	40
Maryland	2, 228, 917	2, 585, 537	1.16	3, 357, 813	2, 899, 572	.86	1, 128, 896	51	314, 035	12
Virginia	43, 079	99, 802	2.32	784, 011	589, 925	.75	740, 932	1719	490, 123	491
West Virginia	1, 829, 844	2, 013, 671	1.10	7, 394, 654	6, 208, 128	.84	5, 564, 810	304	4, 194, 457	208

State.	1900.			Increase of 1900 over 1890.			
	Production.	Value.	Average price per ton.	Product.	Per cent.	Value.	Per cent.
Pennsylvania	79, 842, 326	$77, 438, 545	0.97	55, 965, 316	234	$42, 061, 629	118
Ohio	18, 988, 150	19, 292, 246	1.02	7, 492, 644	65	8, 509, 075	79
Maryland	4, 024, 688	3, 927, 381	.97	666, 875	20	1, 027, 809	35
Virginia	2, 393, 754	2, 123, 222	.89	1, 609, 743	205	1, 533, 297	260
West Virginia	22, 647, 207	18, 416, 871	.81	15, 252, 553	206	12, 208, 743	197

Production of bituminous coal in tons, by counties, from 1891 to 1900, inclusive.

Counties.	1891.	1892.	1893.	1894.	1895.	1896.	1897.	1898.	1899.	1900.
Allegheny	6,216,428	7,227,370.15	6,894,510	6,415,611	7,146,699	7,858,414	7,122,227	9,079,104	9,978,790	10,313,039
Armstrong	299,945	349,561.75	300,222	577,928	649,174	566,771	570,343	843,495	1,037,396	1,290,059
Beaver	139,114	188,379	151,346	135,752	267,863	236,587	183,149	205,395	264,877	273,227
Bedford	413,537	565,760	490,416	288,753	430,804	319,575	353,489	351,091	489,781	530,648
Blair	218,955	278,495	170,144	269,211	351,299	281,237	317,535	202,008	115,701	251,997
Bradford	68,697	53,517	42,739	25,474	57,711	52,467	41,588	22,508	31,835	32,065
Butler	160,273	132,040.50	160,443	134,334	220,895	223,015	227,439	161,224	203,170	251,613
Cambria	3,073,078	3,289,194	3,377,459	3,005,261	4,461,629	4,899,048	5,571,721	6,564,959	7,272,644	11,589,053
Center	490,300	372,431.61	1,259,351	174,548	303,813	445,268	406,482	568,128	872,771	997,820
Clarion	739,068	788,873.25	772,622	401,088	428,675	364,782	581,736	266,476	270,956	366,985
Clearfield	6,706,015.80	6,631,013.18	6,081,324	4,156,310	5,442,299	4,889,793	5,392,472	4,885,780	5,860,397	2,819,109
Clinton	131,619	92,242	94,582	100,000	94,692	134,568	157,388	166,226	221,090	288,881
Elk	739,058	756,652.19	617,878	515,070	602,428	799,669	765,110	873,448	1,212,102	1,246,783
Fayette	5,758,200	7,791,330	6,105,845	6,684,153	10,124,541	8,562,571	10,112,944	13,090,756	14,765,844	15,043,277
Huntingdon	277,938	350,005	291,739	187,070	289,092	333,935	285,676	286,020	327,106	363,243
Indiana	539,628	638,667	359,170	406,878	483,795	392,029	532,989	512,923	619,378	895,547
Jefferson	3,600,052.45	3,682,774.38	3,072,297	3,467,481	4,528,774	4,717,363	5,309,050	6,648,980	6,412,506	6,989,656
Lawrence	172,097.50	119,539	197,277	135,411	227,599	198,666	196,506	186,024	191,224	177,807
Lycoming	....	17,000	53,192	80,160	83,830	82,730	91,735	98,118	101,924	98,064
McKean	15,737	21,058	19,463	19,844	38,207	56,989	47,022	29,631	25,435	27,618
Mercer	579,770	442,632.75	486,049	297,662	502,945	502,317	426,302	340,582	476,618	528,557
Somerset	411,070	423,179	483,770	434,188	521,995	621,980	1,166,327	1,720,662	2,686,299	4,263,239
Sullivan[a]	....	....	....	90,538	....	....	....	....	....	....
Tioga	993,259	964,756	942,252	684,627	781,814	800,658	925,893	917,026	634,301	922,701
Washington	2,407,837	2,726,941	3,414,444	3,373,778	3,410,694	4,366,518	3,761,234	4,661,180	4,779,097	4,884,828
Westmoreland	7,605,867.95	8,696,964.35	7,583,346	7,739,080	10,325,245	8,566,705	10,127,965	11,475,891	14,189,423	14,872,546
Total	41,787,644.70	46,576,576.11	43,421,498	38,000,260	55,813,112	50,273,656	54,674,322	64,247,635	[b] 73,066,943	79,318,362

[a] Since 1894 in Anthracite region.

[b] 26,278 tons of coal, production of small mines not under provisions of law.

Production of coke in tons, by counties, from 1891 to 1900, inclusive.

Counties.	1891.	1892.	1893.	1894.	1895.	1896.	1897.	1898.	1899.	1900.
Allegheny	10,392	12,000	3,000	6,000	5,000	250	4,500	525	...	...
Armstrong	11,314.50	...	6,556	...	...	...	...	...	...	1,000
Beaver	56	...	100	80	...	...	...	...	...	...
Bedford	1,759	25,876	3,000	6,016	40,420	39,200	...	39,708	51,636	101,546
Blair	79,252	101,117	39,361	8,200	28,700	36,943	36,904	20,680	17,932	72,599
Bradford	...	...	...	42,747	142,047	165,435	263,474	...	...	...
Cambria	333,899	217,838	122,219	...	...	...	...	265,282	313,424	318,228
Center	62,976.06	27,600	83,203	13,069	...	...	...	...	...	...
Clearfield	197,793	105,568	131,360	45,574	117,830	157,756	191,040	173,108	227,722	155,451
Elk	2,500	17,181	29,421	8,257	...	...	...	...	293	850
Fayette	3,091,301	4,268,825	3,011,054	3,426,791	5,339,887	3,692,397	4,851,918	5,660,209	6,421,534	6,276,854
Huntingdon	...	4,604	29,103	...	...	...	...	...	3,750	...
Indiana	105,623	40,234	33,620	5,250	7,172	22,798	16,330	15,712	48,760	68,303
Jefferson	439,942	394,494	255,473	219,655	276,578	407,865	445,013	619,731	535,427	536,239
Somerset	26,657	11,745	9,953	5,027	6,862	9,086	...	14,937	23,971	21,799
Tioga	1,982	1,093	984	450	976	1,032	476	503	...	...
Washington	1,000	...	...	...	...	7,200	...	...	...	...
Westmoreland	2,185,096	2,626,454.87	1,700,889.90	1,937,128	2,956,908	2,073,291	2,723,636	3,351,525	4,548,121	4,632,243
Total	6,551,542.50	7,854,629.87	5,459,296.90	5,724,244	8,922,380	6,613,253	8,533,291	10,171,920	12,192,570	12,185,112

The production of coal and coke in each county for 1891–1900, inclusive, is shown in the preceding tables (pp. 190–191), quoted from the report for 1900, by J. E. Roderick, chief of the State bureau of mines. Somewhat more than one-half, or nearly three-fifths, of the production of the State in 1900 was derived from the Pittsburg coal, the balance, about 40 per cent, being derived chiefly from the Lower Kittanning and the two Freeport coals.

The increase or decrease in the output of the counties, shown in the table is also reflected in the numbers of mines in operation. The number of bituminous collieries in Pennsylvania, as listed by Baird Halberstadt in 1892, was 706.[a] The list published by the same author in 1901[b] includes 935 names. The number of new mines opened in the year 1900, as shown by the reports of the mines inspectors, was 175. The number abandoned was 28 mines. Six mines were reopened.

The districts of most rapid development within the last decade include Cambria and Somerset counties, northeastern Indiana County, the Shawmut basin of southwestern Elk County, the Pittsburg coal region of southern Allegheny and southwestern Fayette County, and the Connellsville basin of Westmoreland and Fayette counties. In 1892 the number of mines was 88 in Allegheny, 85 in Fayette, 92 in Westmoreland, 122 in Clearfield, 76 in Cambria, and 19 in Somerset. In 1901 there were 99 in Allegheny, 117 in Fayette, 118 in Westmoreland, 127 in Clearfield, 130 in Cambria, and 53 in Somerset. From this it will be seen that the increase in the number of mines working the Allegheny coals in Cambria and Somerset alone was nearly equal to the total increase in number of operations on the Pittsburg coal in the State. The rapid strides in the coal-mining industry of the two counties last named is further shown by their production during the last few years. A reference to the table shows that the increase of output for 1900 over 1899 from these two counties is over 5,000,000 tons, or nearly three times as much as the increase of the output of Pittsburg coal in Allegheny, Fayette, Westmoreland, and Washington counties.

PROSPECTIVE DEVELOPMENT.

The extraordinary increase in the relative production of Cambria and Somerset counties is largely due to the extensive development of the Allegheny coals in northern and southern Cambria County and northern Somerset County, the horizon receiving particular attention being the Lower Kittanning or its supposed representatives. Eight mines on this coal established within a few years near Windber, in northern Somerset, have already attained a capacity of nearly 2,500,000 tons a year. From the observed thickness and regularity of the beds

[a] Atlas, Summary Final Rept. Second Geol. Surv. Pa., 1894.

[b] General Map of the Bituminous Coal Fields of Pennsylvania. Baird Halberstadt, Pottsville, Pa., 1901.

in this region it would seem that both the Lower and Upper Kittanning coals were destined to be worked over a much greater territory in both of these counties, and especially in Somerset. The lower bed, though rarely thick, is the most reliable and persistent of the Allegheny coals, and it is probable that the continued increase of coal production and the exhaustion of the better areas of the Pittsburg coal will lead to its eventual exploitation over large portions of Clearfield, Indiana, Clarion, Armstrong, and Fayette counties as well. The Upper Kittanning bed is certain of a satisfactory development in the second basin, particularly in northern Somerset County.

The Upper Freeport, which over considerable portions of Cambria, Somerset, and Indiana counties is nearly as good a seam as the Lower Kittanning, should also afford a large territory for operation in Westmoreland County, north of the Loyalhanna, in northeastern Jefferson and southwestern Elk counties, as well as in Clearfield County. Generally, however, it carries a rather large percentage of sulphur. In the Philipsburg-Houtzdale basin this bed has been locally much damaged by the removal of the Lower Freeport or Moshannon coal, which approaches to within 30 feet of it in that district. This exhaustion of the Moshannon coal in eastern Clearfield, shown in the decrease of the production of the county, has led to more detailed development, including the thinner coals remaining in the Snowshoe basin of Center County and the coals of the Freeport group in northern Indiana County.

The Lower Freeport coal in the Central district of the Reynoldsville basin seems to be largely exhausted. Mining in this bed has perhaps reached its climax in the Shawmut district also, and the extension of operations is now chiefly toward the southwest, where much of the area is deeply covered. It would seem that large areas of this bed in Indiana County, in southern Jefferson, and southwestern Clearfield counties would, at the present rate of growth of the industry, be brought into production within a few years, while considerable territory in poorer condition will probably be eventually brought into development in Somerset and Westmoreland counties. The Freeport group will for a long time continue to furnish coal for the numerous manufacturing towns of Beaver and Butler counties.

The approximate exhaustion of the Bloss coal in the Barclay basin threatens abandonment of Bradford County, unless the exigencies of the coal industry permit the operation of the "A" bed. In the Blossburg basin considerable portions, apparently including the best areas of the Bloss bed, have been worked out, though geographic advantage, improved methods of mining and handling, and favorable prices will probably cause its removal over large remaining areas to the west of Arnot and on the south limb of the basin.

The demand for heavy steam and locomotive fuel close at hand has brought about a rapid local development in the Kettle Creek district, Clinton County, as well as in the counties near the northwestern margins of the field. It is not improbable that this demand will lead to the further development of the Brookville and Clarion coals, especially in northern Butler, in Clarion, Jefferson, and southern Elk counties, and the Lower Kittanning in Jefferson County. The development of the Brookville coal along the Allegheny front will perhaps be more dependent on local industrial conditions, or high prices, on account of the proximity of its outcrops to the Kittanning or even the Freeport group. Yet a refinement of the coal industry will not, improbably, lead to the exploitation of the Brookville even in this region, though the product may bear a reduced value rating in the market.

Mining in the Broadtop field is more difficult than in the other bituminous areas on account of the complicated structure in close folds similar to that of the anthracite basins. The result of this folding is a number of steep, irregular, and generally very narrow basins. The Kelly coal appears to be largely mined out in Bedford County where it is of workable thickness. The Barnett coal, which is the source of a large number of operations, extends throughout most of the field and remains untouched over large areas, though it is deeply covered in several of the basins. The Fulton bed, a short distance below the Barnett, is at present worked at several points and offers a still larger area, although it is generally less accessible. This coal appears to be of good quality, coking successfully, and is of a thickness at present workable over much of its territory. It contains a large amount of coal, though, lying just above the Pottsville, it is very deeply buried in the basins over most of the field. In the northern or Huntingdon County portion of this field the available mining territory of the Barnett coal has been seriously damaged by the somewhat desultory operations of a number of small operators having too little capital and unable to deal on a sufficiently large scale with the mining problems arising from the complicated structure of the basins.

Most extensive developments of the Pittsburg bed, including new territory, are now in progress in southwestern Fayette, Washington, and Greene counties. A notable feature of this development is the extension of the coking industry from the Connellsville basin westward into the Monongahela Valley. The general producing power of the fields is touched upon in the discussion of the capacity of the existing mines. The reports for 1900 indicate the early establishment of a large number of new mines. At a number of localities in which the best beds are exhausted, openings are to be made and mines operated in other and thinner beds.

It is a notable fact, well illustrating both the relatively recent date of development and the extent of the coal resources of the State, that shafting or deep sloping has as yet been adopted at but few points in all the bituminous area, and that even in pursuit of the most valuable beds mining has not yet been carried beyond a shaft depth of 630 feet. Of the few shafts in the Allegheny formations none have a depth of 350 feet. There are no "deep" mines in the bituminous basins. The results of test bore holes in Washington and Greene counties indicate the continuity in workable condition of the Pittsburg coal in the interior of the deep southwestern basin. And it is not improbable that this great bed will eventually be wrought at sea level. At the same time the better coals of the Freeport and Kittanning groups are likely to be followed to the axes of the basins of the eastern counties.

METHODS OF MINING.

All but a small percentage of the bituminous coal mines in Pennsylvania are worked by drift on the outcrop or by gentle slope down the dip of the bed. Deep mining, as that term is employed in Europe or in the exploitation of metalliferous deposits, is practically unknown in this territory. In many of the old or small mines the system of single entry is employed; but in nearly all of the larger operations and newer mines double entry has been adopted. The room and pillar system is in vogue in most mines throughout the region.

At the greater number of the large mines in all portions of the field rope, electric, compressed air, or steam haulage has been introduced, and machine mining by electricity or compressed air is now extensively employed. The consolidation of the mines in certain localities under single managements render it practicable to construct plants capable of economically supplying power to several mines from a single station.

The reports of the mine inspectors of the several districts furnish a basis for an estimate of the proportion of mines using machine haulage and cutting of the coal. The inspector for the third bituminous district of the State, including Armstrong, Butler, Clarion, Lawrence, Mercer, Beaver, and portions of Indiana, Jefferson, and Westmoreland counties, reports in 1900 the use of rope haulage at 27 per cent of the mines, electric haulage at 5 per cent, and locomotive traction at 1 per cent. Thirty per cent use cutting machines, compressed air being used in 25 per cent and electric power in 2½ per cent of the total number of mines. In the fourth district, containing the small mines in the northeastern detached basins, as well as a portion of the Reynoldsville basin, rope haulage is used in 27 per cent, electric in 15 per cent, and steam traction in 6 per cent, while 34 per cent use mining machines to some extent, 19 per cent utilizing compressed air and 13 per cent electric power. An estimate of the extent of power application in the Pittsburg region may be based on the returns from the ninth district, including portions of Allegheny, Fayette, and Westmoreland counties, in which we find 60 per cent of the mines using rope haulage, 6½ per cent electric, 6½ steam, and 2 per cent air traction, while machine cutting has been introduced into 37 per cent, compressed air being employed in 33 per cent and electric power in 4 per cent of the mines. In 1900 the number of cutting machines increased from 1,343 to 1,786, nearly two-thirds being pick machines and about one-third chain machines. Nearly 34 per cent of the total product in 1900 was machine cut, 80 per cent of the increase for the year being accomplished by the extended use of machines.

DISTRIBUTION OF THE PRODUCTS.

The distribution of the production of the bituminous coal mines in Pennsylvania is governed largely by the geographic positions of the mines with reference to the main body of the field and the direction of the communicating railways. To a certain extent the distribution is specially adjusted to the qualities of the fuel; but ordinarily, unless the product has some special or important adaptation, the markets are so favorably situated that the coal is apt to move east or west or north according to its initial geographic position. The southward movement is to a great degree an exception to this rule.

The coal of the Barclay and the Ralston basins,[a] the farthest northeastern bituminous supply points, is largely taken in hand at once for railway use. The Bloss coal, of Tioga County, famous as a smithing coal, has a wide circulation throughout the Northeastern States, Canada, and throughout the West as well, though much of the product of the other northern basins has been marketed under the same name. Its high fuel ratio makes it highly prized for domestic and steam use also. The coals of the Broadtop field also are semibituminous. A part of their product is coked for near-by furnaces. The remainder is mostly devoted to factory use in the Eastern cities, where it is especially valued on account of its smokeless character. The coal from the Barnett bed is an excellent heavy steam coal, and serves well for marine boiler use.

The low percentage of volatile hydrocarbons in the coals near the eastern margin of the Allegheny plateau brings favor to them also for Eastern manufacturing purposes. The fuel from the Berlin basin in Somerset County is marketed as a relatively smokeless steam coal, some of the product being shipped from lake ports, as well as to the eastward. A portion of the fuel from the Pittsburg coal in the Salisbury basin has an extended market as a rolling mill and smithing coal, and as such is distributed to some extent to the westward, though the main body of the output finds an eastern outlet. At several points the Lower Kittanning is said to furnish a high grade of forge coal in Cambria County. The large portion, however, of the production of Somerset, Cambria, and Blair counties is shipped as steam and manufacturing coal to tide water at Baltimore, Philadelphia, or New York, whence a part is reported to be exported. Coal from this district is said to reach south as far as Fredericksburg, and northeastward along the

[a] The output of these basins is shown in table on p. 190, under Bradford and Lycoming counties, respectively.

Atlantic coast. A relatively small amount of the coal from the Lower Kittanning, Upper Freeport, and Pittsburg beds is coked in these counties. At a number of mines in Clearfield County, the product from the Lower Kittanning and the Moshannon beds is coked for shipment.[a] In general, however, the coals of the central and eastern portions of the county constitute an excellent high grade steam fuel, while the product of a few mines is well suited to puddling, smelting, or rolling mill use. The coal from this region is carried chiefly to the north and east—to Ontario, Quebec, and to New England—as well as to tide water at Philadelphia and New York. The Center County product is for the most part carried eastward for locomotive consumption.

The Lower Freeport, celebrated in the Reynoldsville region, is coked in limited amounts in the Shawmut district, and quite extensively in the Punxsutawney district of southern Jefferson and northern Indiana counties. It is an exceptionally pure fuel, adapted to gas or high grade steam purposes. The basin is tapped by the Buffalo, Rochester, and Pittsburg, the Erie, New York Central, and the Pennsylvania systems, by which this coal is distributed chiefly to the north and east, reaching the north and lake ports as well as New England and tide water.

The output of southern Indiana County is largely devoted to railway use, as is the total product of McKean County and the St. Mary's basin in Elk County. The coal of southern Clarion and northern Armstrong and northern Butler and Mercer counties is in general suited to railway use, and as such a large portion finds its way to western New York, Ohio, the Great Lakes, and Canada. The product of southern Armstrong, Beaver, and Lawrence counties is largely consumed in the industries of the many manufacturing cities of the region.

The Pittsburg bed of southwestern Pennsylvania is the standard gas and coking coal in North America. It has a high reputation also as a steam coal. Of the enormous tonnage from this bed, including about three-fifths of the total production of bituminous coal in the State, a considerable proportion is consumed in the iron industries and innumerable other manufactory establishments in Pittsburg and the neighboring cities of western Pennsylvania and eastern Ohio. The famous Connellsville coke is distributed throughout the northeastern United States, Canada, the Western States, and Mexico. The Pittsburg gas coal is distributed from the Atlantic ocean to the Rocky Mountains. Shipments are made to tide water at Baltimore, Philadelphia, and New York, or on the Gulf of Mexico by way of barges down the Monongahela and Ohio rivers. A large portion of the consignments to the Southwestern and Gulf States as well as Mexico are transported by the water route.

[a] The coke production of the counties is shown in the table on p. 191.

As will have been seen, the chief sources for export coal are the Pittsburg coal region, the Reynoldsville basin, and the Cambria-Somerset district, the greater portion being drawn from the districts first and last named. The reports at hand lack sufficient data as to the proportion of bituminous coal that is really carried from Pennsylvania to foreign countries outside of Canada, since in most cases the coal is billed only to tide water, where it is utilized for local consumption or coastwise distribution.

The bituminous coal fields of Pennsylvania are penetrated by the numerous lines of the Baltimore and Ohio, Pennsylvania, New York Central, Erie, and Lake Shore systems, as well as by the Buffalo, Rochester and Pittsburg, and Pittsburg, Bessemer and Lake Erie railways. A great tonnage is transferred by barges down the slack-water Monongahela and Ohio rivers. The Barclay basin is indirectly reached by the Lehigh Valley Railway, while the coal fields are approached by the Philadelphia and Reading and the Delaware, Lackawanna and Western railways.

In the eastern districts the product, especially that of the smaller mines, is often sold to the railways at the mine. From the meager reports as to the railway tariffs from the other mines it would appear that considerable differences exist in the rates even from near-by points. In general, however, the transportation tariffs may be learned from the published interstate freight schedules.

CAPACITY OF THE MINES.

The reports from the mines indicate that the present capacity of the existing mines in excess of the current production is from 25 to 35 per cent. This possible increase of production would appear to be slightly greater in the mines outside of the Pittsburg region. The production of the Monongahela district recorded in the table given above is doubtless much smaller than would have been the case but for the low water of the river and the consequent long interruption of navigation in 1900.

The average number of days in which the mines of the bituminous regions were in operation during 1900 varied from 181 in the eighth inspection district to 261 in the ninth district. In general the steadiest operation was in the coking districts. The average period of operation during the year for the entire region was two hundred and nineteen days. From this it would appear that the output would be very greatly increased by continuing the operations more steadily. But it is doubtful, on the other hand, whether the supply of railway cars and other transportation facilities, which, in fact, are reported to have been inadequate in portions of the eastern districts and in the Pittsburg region, would have been sufficient for the operation of all the mines to their full capacity.

COST OF MINING.

The cost of mining in the bituminous fields varies greatly in different areas, the rates being governed primarily by the thickness and structure of the bed, though they are also affected by general geographic location, and the relations of the mine to the wage-scale districts. In Tioga the miner is paid from 75 to 82 cents per ton r. o. m., pick mining, the average being 80 cents. From the mine reports it appears that in the Broadtop field, and in Lycoming, Clinton, Center, Cameron, Elk, and Jefferson counties, 60 cents per ton r. o. m. is paid for pick mining. In Clearfield County 54 to 70 cents, averaging 60 cents r. o. m., is paid for pick work, and 35⅝ for loading, and 8 to 10 cents for cutting where machines are used. In Blair and Cambria counties 53½ to 68 cents, averaging about 58 cents r. o. m., is paid for pick work, and 24 to 45 cents for loading machine-cut coal. In Somerset the returns indicate a cost of 53 to 65, generally 55 cents, r. o. m. for hand mining, while loading costs 35 in the thin beds and 33 in the thick. Pick mining, run of mine, is reported to cost 53½ in Clarion, about 57 in Armstrong, 52½ to 55, averaging 57.5, in the thin coals of Westmoreland, 45 in Mercer, 45 to 50, averaging about 46½, in Butler, 48 to 79 in Beaver, 45 to 60 in the thin beds of Armstrong County, and 40 to 43 in the thin coal in Allegheny County. Loading machine-cut coal r. o. m. appears to cost 33⅝ cents in Jefferson, 35, with 12½ for cutting, in Clarion, and 43 in Armstrong. Where a screen varying from 1 to 1½ inches is used, as in the southwestern corner of the State, pick mining costs 75 to 85 cents per ton in Lawrence and Beaver counties and in the thin coals of Westmoreland.

The rate for mining the Pittsburg coal in Allegheny, Westmoreland, Fayette, and Washington counties is less on account of the greater thickness of the bed and ease in handling the output. However, the scale is complicated in this district, varying considerably, chiefly according to the condition of the bed and the character of the screening. In this region and bed the scale is reported to vary from 40 to 57 cents per ton r. o. m. for pick mining[a] and 23.46 to 28.12 cents for loading, with 4.78 to 7.43 for cutting where machines are used. At a large number of mines at which the coal is screened it appears that pick mining costs 65 cents per ton with a three-quarter inch screen, 75 cents with a 1-inch screen, or 80 with a 1¼-inch screen, the loading costs 40.5 to 57.25 per ton, according to the conditions.[b] At a large number of mines in Allegheny and Westmoreland counties the scale for mining the Pittsburg coal is 51.71 cents for pick work r. o. m., and 9.57 and 6.14 for machine work, or 80 cents for pick work, where a 1¼ screen is used, and 15 and 9.5 cents for machine work. At other points,

[a] 40, 42, 43.18, 48, 49, 51.71, 52.5, 55, and 57.5.

[b] Following is an illustration of the machine scale at a mine using a 1¼-inch screen: Cutting room, 7.4; cutting entry, 10.3; loading room, 36.8; loading entry, 45.04.

especially in Fayette County, 43.18 cents per ton r. o. m. is paid for hand work, and 7.43 and 4.78 for machine work, the rates being 66.8, 11.5, and 7.4, respectively, where the screen is used. At a number of the mines the Pittsburg coal is dug by hand at a rate of from 42½ to 46 cents per "wagon" or car of 34 bushels capacity, while at others, especially in the Connelsville region, the coal is dug by pick at 35 cents per ton r. o. m., or $1.25 to $1.45 per 100 bushels.

The reports from mines in the same district vary widely as to the cost of production of the coal f. o. b. From the statements of the operators the total cost in cents per ton for mining, cleaning, and placing the coal in the car varies somewhat, as follows: Lycoming, about 107; Huntingdon and Bedford, 95; Center, 80 to 88, averaging about 86; Clearfield, 75 to 95, averaging about 85; Blair and Cambria, 75 to 110, averaging, perhaps, 84; Somerset, 70 to 110, approximately 77 for the thin coals; McKean, 115; Jefferson, 68 to 80, averaging about 75; Armstrong, 65 to 80, averaging 74; Westmoreland thin coals, 75 to 90, averaging about 80; Butler, 65 to 85, averaging about 78; Lawrence, 90 to 115; Beaver, 80 to 130, averaging about 90; Allegheny thin coals, 70 to 110, averaging about 77 per ton. The reported cost in the Pittsburg region varies from 47½ cents to $1 per ton. These reports indicate, however, that at many of the mines in this region the cost of production is about 50 to 60 cents per ton. It is not improbable that in many of the reports the expense of royalties or other charges is included in the cost of production, and this may largely account for the variation in cost. Taking this into view, together with the fact that very many of the larger companies have not stated the cost of production, it will be seen that no great reliance can be placed on the figures quoted above.

The table of production of bituminous coal by counties given on page 190 shows the entire number of men engaged in and about the mines in 1900 to have been 109,018. Of the total production, 79,318,362 tons, an average of 727.5 tons of coal was therefore produced during the year for each man employed.[a] The inspectors report the number of days in 1900 during which the mines were in operation to have varied from an average of 181 in the eighth district to an average of 261 in the ninth district, the average for the entire bituminous regions being 219. Accordingly, we may conclude that the output of the whole region averaged 3.322 tons per day worked for each man employed in and about the mines. These averages suggest that, with an extension of the market so as to increase the demand, the mines might, in many cases at least, be kept in active operation for a greater number of days during the year, if not to their full capacity, thus utilizing the capacity of the men while cheapening to some extent the cost of production.

[a] The proportion of men working outside of the mines varies from about ⅙ to ⅓ of the total number of employees in the different districts. The 727.5 tons includes every man about the mines in the employ of the companies.

THE BITUMINOUS COAL FIELD OF MARYLAND.

By David White.

AREA AND STRUCTURE OF THE FIELD.

The Coal Measures of Maryland are a southward continuation of those in the basins of Somerset County, Pa. They occupy a strip along the western border of Allegany County about 20 miles long and averaging 5 miles in width, and cover the greater portion of Garrett County.[a]

The Coal Measures lie in three broad, open, northeast-southwest synclinal folds which define the major basins. Throughout most of their extent in the State the separating anticlines are eroded to the Lower Carboniferous or Devonian rocks, so that these basins are generally distinct. The easternmost is the Potomac basin, sometimes known also as the Cumberland basin. The Maryland portion of this basin includes the regions locally called the Frostburg, the Georges Creek, and the western portions of the Elk Garden and Upper Potomac basins. The northern portion of the Frostburg basin extending northward across the State and spooning out in southeastern Somerset County, Pa., is called the Wellersburg basin in the latter State. These names apply more properly to geographic divisions of one basin than to definite subdivisions.

The Potomac is by far the most important of the three main basins, by reason of its more strongly marked synclinal form, and consequently greater depth and added coal contents; its geographical advantage with reference to tide water and the Eastern markets; and the accessibility of the coals along the relatively deep Potomac erosion system which traverses the axis of the basin. South of Piedmont nearly all of the western half of the basin is in Garrett County, while north of the Potomac River its entire breadth is within Allegany and Garrett counties, the axis lying within the former county. The Potomac basin is the chief source of coal in Maryland, the greater portion of the coal output of the State being derived from the "Big" or Pittsburg bed.

The Savage Mountain anticline separates the Potomac basin from the First bituminous basin of Pennsylvania, which in passing southward embraces the Wilmore and Berlin basins within Pennsylvania and the Salisbury basin, the broad extension of the latter constituting the Second or Castleman basin of Maryland. This basin is elevated and warped where it spoons out to the south in Garrett County, and is so shallow as to include only the lower beds of the Coal Measures in a considerable portion of its area. It is drained by the Castleman River.

[a] The Coal Measures cover somewhat over half of this county, whose total area is 681 square miles.

The third principal syncline, generally known as the Youghiogheny basin, lying between the Viaduct axis and the Laurel Hill anticline, includes a Lower Youghiogheny basin to the northwestward and an Upper Youghiogheny basin, which lies in an offset fold, entering the county from the west and dovetailing between the southern end of the Lower Youghiogheny and the Castleman basins. The Lower Youghiogheny is the continuation of the Second great bituminous basin of Pennsylvania. It includes the northwestern portion of Garrett County. The Maryland area of the Youghiogheny basins, as well as of the middle (Castleman) basin, is but little developed commercially on account of the general lack of railway facilities and the geographic advantage of the eastern basin with its enormously thick Big bed.

FORMATIONS OF THE COAL BASINS.[a]

In general the formations recognized in the bituminous coal fields of southern Pennsylvania are found to extend with minor, often local, modifications southward across western Maryland. The Pottsville, 375 feet thick in the northern portion of the Potomac basin, where it has the same general characters as in eastern Somerset County, Pa., increases to about 500 feet in thickness near the southern boundary of the State. It corresponds very closely to the Blackwater formation described by J. A. Taff and N. H. Darton in the Piedmont folio of the United States Geologic Atlas. The Allegheny formation measures about 300 feet in thickness and appears to be fairly uniform in this region, although certain of its coals have not been noted in portions of the basins. This formation includes the terranes described from the Piedmont quadrangle as the Savage formation, and that portion of the Bayard formation extending up to and including the Thomas coal, the remaining upper portion of the Bayard being regarded by the Maryland geologists as representing the lower part of the Conemaugh. The Conemaugh formation presents the same general conditions as are found in this formation in Somerset County, Pa., it being destitute of the red-shale beds in its upper portion, while at the same time carrying one or more beds of valuable coal of workable thickness. As measured by Prosser near Barton it is about 630 feet in thickness. The Conemaugh includes the upper part of the Bayard and the entire Fairfax formation described in the Piedmont folio.

The Monongahela formation, corresponding to the Elk Garden formation of the northern West Virginia region, has a thickness of approximately 230 feet and, beginning with the Big or Elk Garden bed at the base, includes supposed representatives of the Redstone,

[a] The most excellent detailed work of the geologists of the geological survey of Maryland has resulted not only in the tracing of the formation boundaries southward from Pennsylvania, but also in the identification of the coals with the Pennsylvania series. Accordingly, the nomenclature here used is that given in the Allegheny County report of the State survey. Special acknowledgement is due to Prof. W. B. Clark, State Geologist, and Dr. G. C. Martin, assistant geologist, for information communicated to the writer in advance of the publication of their report on Garrett County.

Sewickley, and Waynesburg coals. The Monongahela is surmounted by about 400 feet of beds which are referred to the Dunkard formation. This formation, the Dunkard, whose lower beds only are represented in the Maryland region, differs in character from the Monongahela only in the diminution of the coal and a slight increase of limestone.

A section of the Upper Carboniferous from the Waynesburg coal downward in the Potomac basin is as follows:

Section of Maryland coal measures from the Waynesburg coal to the base of the Pottsville formation.

	Ft.	in.
MONONGAHELA FORMATION (XV).[a]		
Koontz or Waynesburg coal	0	0
Surface material	8	5
Limestone, with bowlders	5	7
Siliceous fire clay	3	11
Shale and sandstones	27	4
Coal	0	5
Shale and sandstone	57	10
Coal (Tyson), with 3-foot parting	5	6
Shales and sandstones	46	0
Coal	2	6
Shale and thin sandstone	28	4
Limestone	5	6
Shale	7	8
Coal and shale, Redstone	7	4
Shale and sandstone	19	11
Coal and shale	3	7
Big bed, Elk Garden, or Pittsburg coal	9	6
	239	4
CONEMAUGH FORMATION (XIV).[b]		
Black shale with thin layers of sandstone	41	6
Concealed in part	93	6
Sandstone and shales	14	6
Franklin, or "Dirty nine-foot," coal with partings	10	4
Fire clay and shales	24	0
Sandstone and concealed	25	6
Coal	0	3
Concealed and drab shales	31	6
Coal	0	9
Shales	71	9
Shales with limestone concretions	21	0
Shales, sandstone, and concealed	54	9
Shales and concealed, probably containing the Barton coal	39	6
Coal	0	4
Shales, sandstone, and fire clay	119	6
Coal	1	9
Fire clay	2	6

[a] Consolidated Coal Company shaft, 2 miles south of Frostburg. Geol. Surv. Md., Rept. Allegany Co., p. 127.

[b] Prosser's measurement, Phoenix Hill, 2 miles south of Barton. Op. cit., pp. 122, 123 (condensed).

	Ft.	in.
Shales, sandstone, and concealed	36	9
Olive to yellowish shales	11	6
Massive sandstone (Mahoning), shale, and concealed	33	6
	630	

ALLEGHENY FORMATION (XIII).[a]

	Ft.	in.
Coal, Upper Freeport, "Thomas" — coal	2	0
Coal, Upper Freeport, "Thomas" — shale and bone	1	0
Coal, Upper Freeport, "Thomas" — coal	2	0
Concealed	10	0
Shale, bluish	10	0
Coal, Lower Freeport	2	0
Fire clay	2	0
Concealed	10	0
Sandstone, hard	2	0
Sandstone, shaly	5	0
Shales, sandstones and concealed	55	0
Coal, Upper Kittanning — bituminous shale	5	0
Coal, Upper Kittanning — coal	2	0
Dark shales and concealed	10	0
Massive sandstone, gray	50	0
Shales, drab	5	0
Coal, Lower Kittanning, "Davis" — coal, shaly	1	0
Coal, Lower Kittanning, "Davis" — coal, bony	0	8
Coal, Lower Kittanning, "Davis" — coal, good	1	4
Coal, Lower Kittanning, "Davis" — slate, hard	0	½
Coal, Lower Kittanning, "Davis" — coal, good	2	6
Fire clay, sandy	3	0
Shales with nodular iron ore	2	0
Fire clay, impure	4	0
Flaggy sandstone	20	0
Concealed	25	0
Fire clay, sandy	10	0
Flaggy sandstone and sandy shales	25	0
Concealed and sandy shales	40	0
	307	6½

POTTSVILLE FORMATION (XII).[b]

	Ft.	in.
Sandstone, massive, Homewood	20	0
Coal, often impure, Westernport or "Two-foot" bed	2	0
Shale and heavy sandstone	85	0
Shale with coal streaks	30	0
Flaggy sandstone and shale	12	0
Coal	1	6
Impure fire clay	8	0
Flaggy sandstone	14	0
Coal, Bloomington or "Railroad" bed	1	6
Shale, flaggy sandstone and concealed	80	0
Coal and coaly shale	3	0
Black, yellow, and gray arenaceous shales	7	0
Greenish flaggy sandstone	30	0
	296	0

[a] Vicinity of Westernport. I. C. White, Bull. U. S. Geol. Surv. No. 65, p. 186.
[b] Vicinity of Westernport. Geol. Surv. Md., Rept. Allegany Co., p. 114.

The Dunkard and the Monongahela formations are present in Maryland only in the Potomac basin, and it is the magnificent coal of the Big or 14-foot bed in the latter formation that has led to the extensive and preponderant development of this basin, and established a national reputation for the "Cumberland coal."

COALS OF THE POTTSVILLE FORMATION.

The composition of the Pottsville formation, which is practically identical with the Blackwater, is essentially the same in western Maryland as along the Allegheny escarpment in southern Pennsylvania. As in the latter State, it generally extends to the crest of the mountains on either side and forms the rim of the coal field, which owes its wide area to the support of the resisting sandstones of this formation. Its thickness is nearly 300 feet to the northeastward, about 500 feet near the southeast corner of Garrett County, and about 325 feet in western Garrett County. The Homewood sandstone is generally distinct. The Conoquenessing sandstone is quite variable, as are also the basal sandstones.

The coals of the formation are irregular, and though of good quality locally, they do not appear to be anywhere sufficiently thick for competition with the better beds of the Allegheny and higher formations. They contain, however, a considerable amount of coal that in places may eventually demand consideration.

BLOOMINGTON COAL.

The lowest coal sufficiently thick to deserve mention in the Maryland district is that locally known as the Bloomington or Railroad coal. This seam, which occurs about 120 feet above the base of the formation, is unreliable, like other coals of this formation, varying, even within short distances, from 1 foot or less to nearly 3 feet in thickness.

MERCER GROUP.

To this group belongs the patchy coal which usually overlies the Mount Savage fire clay, and which is known as the Mount Savage coal. This coal is very irregular, sometimes reaching a thickness of 4 feet, though averaging about 2 feet. It is extracted at the clay mines and used in firing the brick, though it is generally too sulphurous for the market.

The bed known in the Potomac basin as the Westernport, or Two-foot coal, worked to a slight extent near Westernport, appears also to belong to this group, and it may be the representative of the Mount Savage coal about Piedmont. It lies about 115 feet above the Bloomington coal and is said to be but 20 feet below the top of the Pottsville. Its thickness usually averages about 2 feet 10 inches to

3 feet. Where exposed near Westernport it presents an upper bench 1 foot 8 inches thick, separated by a 1-foot shale parting from a lower bench 1 foot 3 inches thick, which is locally highly sulphurous.

COALS OF THE ALLEGHENY FORMATION.

In its general characters this formation is the same in Maryland as along the Allegheny escarpment in Pennsylvania, the chief differences being the general thinning or disappearance of the limestones to the eastward. The Allegheny, which includes the Savage and the greater part of the Bayard formations of the Elk Garden and Upper Potomac basins, has a moderate exposure zone in the Georges Creek and Frostburg districts. It is accessible along the axis of the basin on the Potomac River, and it is the surface formation throughout a large portion of the Salisbury and Youghiogheny basins. It has a thickness usually of a little over 300 feet in the Potomac region, and about 250 to 275 feet in the basin of the Youghiogheny.

It contains several coals of workable thickness and quality, although they have generally been neglected, except in the Youghiogheny and the Upper Potomac basins, for the greatly overshadowing Big bed or Pittsburg coal. Nevertheless, even in the Potomac basin the area of the Allegheny coals is so much greater as compared with that of the Big bed that their volume in workable thickness is far greater than that of the latter.

The more persistent of the Allegheny coals are the Bluebaugh, the Parker, the Davis or Six-foot, and the Thomas or Three-foot beds. The most important bed of the formation is that known as the Davis coal. On account of their stratigraphic and lithologic relations, these coals have been tentatively correlated with the Brookville, Clarion, Middle Kittanning, and Upper Freeport coals respectively, of the Pennsylvania sections.

BLUEBAUGH COAL.

This coal, which lies but a few feet above the top of the Pottsville formation, and which is supposed to represent the Brookville coal of Pennsylvania, is reported to be largely confined to the northeastern border of the Georges Creek district, where at a small mine near Warrior Run it shows three benches of coal, 1 foot, 3 feet 4 inches, and 1 foot 1 inch in thickness, separated by two partings, the upper of which is 1 foot 4 inches and the lower but 1 inch thick. The seam is variable as to both thickness and the proportion of shale. This bed, which is about 18 inches in thickness below Coketon, W. Va., probably occurs in portions at least of the western districts of the State.

PARKER COAL.

This coal has been proved to some extent in the region of the Potomac basin occupied by the Bluebaugh bed, which lies 30 feet below it. On stratigraphic grounds the Parker coal has been tentatively correlated with the Clarion coal of Pennsylvania. It ranges from a few inches to nearly 5 feet in thickness, but is apt to contain considerable shale in the thicker exposures. Near Barrelville, where the seam has been worked, it presents an 8-inch upper bench, separated by 6 inches of shaly standstone from the lower 2-foot bench. Its greatest thickness has been observed southward, toward Warrior Run.

DAVIS COAL.

The third coal of the Allegheny formation, locally known as the Davis or Six-foot seam, is a well recognized and persistent bed, and is, next to the Elk Garden, the most important coal in Maryland. This bed, which forms the base of the Savage formation in the Piedmont quadrangle, lies about 125 to 150 feet above the Pottsville, and is generally regarded as representing the Lower Kittanning coal of Pennsylvania. Near the Pennsylvania line it has attracted little attention, but in the Georges Creek district, where it often exceeds 6 feet in thickness, it is locally a very valuable bed, though much broken by partings. Here a typical section shows: Bone coal, 2 inches; top coal, 10 inches; Bone, 6 inches; coal, 1 foot 11 inches; parting, ½ inch; coal, 2 feet 2 inches. Toward the north the bottom bench is locally sulphurous. Southward this bed improves greatly and is mined at a number of points near Piedmont and in the north Potomac Valley. Opposite Chaffee it is 6 feet 6 inches thick in two benches separated by a thick band of shale. On Glade Run it is 7 feet 8 inches with a thick parting. The Davis coal does not appear to be mined to any extent in the western basins except near Corinth where a good coking coal 3 feet 9 inches thick is supposed to represent this horizon in the Youghiogheny basin. Still farther south, near the head of Sand Run, the bed measures 8 feet 11 inches, and near the corner of the State becomes cleaner and produces an excellent grade of coke.

THOMAS COAL.

This bed, locally known as the Three-foot coal, lies at the base of the sandstone supposed to be the Mahoning, and is accordingly correlated with the Upper Freeport horizon. In the Georges Creek district the Thomas coal measures from 2 feet 6 inches to 3 feet 2 inches. In this region it typically contains a thin 3 to 5 inch bony coal bench separated by a bone parting from the lower bench 2 feet 10 inches in thickness. Southward the upper bench improves in quality and is merchantable. At Bayard the bed has a thickness of 5 feet 6 inches, and near Fairfax Knob it exceeds 6 feet, the lower bench showing great regularity and a uniform thickness of nearly 3 feet.

COALS OF THE CONEMAUGH FORMATION.

In the Potomac basin, as in the Berlin basin of Pennsylvania, the Conemaugh is notable for containing one or more important coals, which toward the eastern border of the Appalachian trough are somewhat less variable than in the interior.

BARTON COAL.

In Maryland the Barton or Four-foot bed is the best coal of the Conemaugh formation, and one of the most important thin coals of the northern half of the Potomac basin. It occurs about 250 feet above the base of the Conemaugh and 425 feet below the Pittsburg coal. In the Georges Creek region, where it is mined to some extent, it varies in thickness from 2 feet to 3 feet 6 inches, and yields on the average 2 feet 6 inches of clean coal in one bench. On account of the stratigraphic position of the Barton coal it has tentatively been referred to the horizon of the Bakerstown coal. The bed offers a very valuable source of fuel for eventual exploitation in western Maryland.

FRANKLIN COAL.

In the Georges Creek Valley a coal, locally known as the Dirty nine-foot bed, is well exposed near the Franklin plane, where it contains 2 feet 3 inches of coal beneath 8 feet of shale and coal streaks. This coal, which has been opened at a number of points, varies from 5 feet 10 inches to 10 feet 4 inches in total thickness, though it is generally of no importance. The bed, which is supposed to belong to the horizon of the Little Clarksburg coal, is not likely to prove of value for more than local use throughout this basin.

COALS OF THE MONONGAHELA FORMATION.

In Maryland this formation is confined to the Potomac basin, and by far the greater area of the formation in this basin is in Allegany and Garrett counties, the largest part being contained in the former. The Monongahela is noted for the extraordinary thickness and purity of its basal member, the Elk Garden coal. The thin higher coals of the formation are of less value by far than the coals of the Allegheny formation.

ELK GARDEN COAL.

By reason of its purity, easy accessibility, and remarkable thickness, the Elk Garden or Fourteen-foot bed has from the first been the principal source of coal in Maryland. With an area in the State of about 35 square miles, in round numbers, of which all but about 2 square miles lies in the Georges Creek and Frostburg districts of the Potomac basin, and with its almost complete dissection and exposure along the axis of the basin or by side streams, the Big bed has monopolized the trade, while creating and sustaining the great name of the Cumberland coal. Its ease of production has brought about the general neglect of the "thin coals" which, in the northern Frostburg district and in the Salisbury and Youghiogheny basins, can hardly be said to have even been fairly prospected.

The Elk Garden bed, which was made the base of the Elk Garden formation in the Piedmont quadrangle, is generally considered as representing the Pittsburg coal in this region. In a general way the coal thickens from about 5 to 6 feet in the northern part of the basin to 14 and even 20 feet in the vicinity of Elk Garden. It carries thin, persistent partings, separating the bed into a "roof" coal, a "breast" coal, and a "bottom" coal. The roof bench varies somewhat in constitution and value, and in portions of the basin it is wholly or in part kept as roofing. The "breast" bench, the most important, is but about 2 feet thick north of Frostburg, but it thickens southward, often exceeding 7 feet, without impurities, south of Lonaconing. The "bottom" coal, 2 feet 6 inches to 3 feet thick, was formerly undisturbed in the mines on account of two thin shale bands. Improved methods in handling the coal now render this bench economically workable. Quite contrary to the general rule the shale partings generally thin, even as the benches thicken, in passing southward, so that near Franklin the bed contains over 14 feet of workable coal, while at Elk Garden the coal is said to swell to nearly 20 feet, all except a thin shale parting near the base being productive.

A typical section near Lonaconing, in the Georges Creek district, reported by the State geological survey, shows:

	Ft.	in.
Coal	1	0
Fire clay	1	0
Roof coal	2	0
Bony coal	0	8
Breast coal	8	0
Shale	1	0
Coal	0	4
Shale	1	0
Coal	1	0
Shale	0	¼
Coal	0	10

The coal is mostly columnar and brilliant, though portions are shaly in structure and dull.

The fuel everywhere known to the trade as Cumberland coal[a] is one of the highest grades of steam coals known. It is semibituminous, containing an average of about 19 per cent volatile hydrocarbons, 74

[a] Although the term was formerly borne almost exclusively by the coal from the Elk Garden seam, its application has gradually been extended to cover the coal output of the basin.

per cent fixed carbon, less than 6 per cent ash, and less than 1 per cent sulphur.

The coal, which is largely exhausted except in the region of Frostburg, furnished over 90 per cent of the production of the State in 1900.

TYSON COAL.

The first coal of importance[a] above the Elk Garden is known as the Tyson or Gas bed, which, on account of its position, 120 feet above the Big bed, has tentatively been correlated with the Sewickley coal by the Maryland geologists. The bed ranges from 4 feet to 7 feet 3 inches, with an average thickness of about 6 feet 2 inches. It is cut by thin partings into a top coal 12 inches or more in thickness, a middle bench 3 to 4 feet thick, and a bottom bench 1 foot to 1 foot 6 inches in thickness. In the vicinity of Franklin, where the bed was formerly mined to some extent, this seam is reported to contain 7 feet of workable coal, but near Lonaconing its thickness is hardly 4 feet. The coal is inferior to the Big bed in quality, and the seam is generally considered of less value than the better coals of the Allegheny and Conemaugh formations.

KOONTZ COAL.

In the several small areas of higher Coal Measures in the Georges Creek district a coal seam, known as the Koontz bed, occurs about 230 to 250 feet above the Elk Garden coal. This coal, which varies from 5 feet 9 inches to 7 feet 9 inches in thickness, is much broken up by partings, a typical section showing: coal, 2 feet 3 inches; bone, 4 inches; coal, 6 inches; bone, 7 inches; coal, 1 foot 3 inches; shale, 10 inches; and coal, 5 inches. Near the head of Koontz Run, where the bed has been mined to some extent, it has been found to be further seriously injured by a large number of fissures. On account of its stratigraphic position the Koontz coal is generally supposed to lie at the horizon of the Waynesburg bed of Pennsylvania, and it is therefore made the topmost member of the Monongahela formation in the Maryland section.

The Dunkard formation, next above the Koontz bed and supposed by some geologists to be of Permian age, does not appear to contain any coals of importance in Maryland.

CHARACTER OF THE MARYLAND COALS.

The reputation of Cumberland coal, as the coal production of the Potomac basin is generally known, is founded on the excellent qualities of the Big bed, which, until within a score of years, was almost

[a] A thin coal tentatively correlated by the State geologists with the Redstone coal of Pennsylvania was cut in the Borden shaft, where it is reported to embrace a thickness of 7 feet 4 inches, including the accompanying shale. At another point it is said locally to contain 4 feet 6 inches of coal.

exclusively the source of the State's output. This coal has a national reputation as a high-grade steam coal, for which it is especially adapted, while the product of a number of the mines has an enormous patronage, even extending to foreign countries, as a fine blacksmith and forge fuel. Though high in fixed carbon the coal cokes satisfactorily; but no coke is now reported to be made in this field, on account of the greater profit in the sale of the raw fuel.

The following analyses indicate the constitution of the better developments of the coals in the Potomac basin. Numbers 3–6 are quoted from Johnson's Navy Report; the sixth analysis purports to have been made at the Washington Navy-Yard. The analyses of the Thomas and Davis coals were made in the State and Federal Survey laboratories.

No.	Coal.	Volatile combustible matter.	Fixed carbon.	Sulphur.	Ash.	Water.	Fuel ratio.	Analysis by—
1	Tyson	20.45	69.38	1.56	9.63	0.54	3.392	Maryland Geological Survey.
2	Elk Garden	14.811	80.329	....	4.056	.804	5.423	Johnson, U. S. Navy.
3	.....do	15.158	77.252	....	6.520	1.070	5.096	Do.
4	.....do	15.237	74.761	....	9.109	.893	4.906	Do.
5	.....do	15.807	75.902	....	7.398	.893	4.854	Do.
6	.....do	14.94	78.29	....	5.56	1.21	5.24	Washington Navy-Yard.
7	Elk Garden (?)	21.18	74.38	.74	3.05	.65	3.511	J. S. Casy.
8	Barton	19.02	69.73	1.11	10.43	.82	3.666	Maryland Geological Survey.
9	.....do	17.81	72.68	1.22	8.89	.62	4.080	Do.
10	Thomas	17.15	71.40	1.24	10.74	.72	4.163	Do.
11	Thomas (upper)	22.87	65.60	.64	10.89	.64	2.868	U. S. Geological Survey.
12	Thomas (middle)	23.88	65.99	1.39	9.45	.68	2.763	Do.
13	Thomas (bottom)	22.90	72.76	.59	3.38	.96	3.177	Do.
14	Davis	26.84	67.18	1.68	5.18	.80	2.502	Do.
15	.....do	22.03	70.53	.924	6.74	.70	3.201	Do.
16	.....do	17.12	71.08	1.40	11.29	.50	4.151	Maryland Geological Survey.
17	.....do	16.50	75.21	1.05	8.08	.47	4.558	Do.

DEVELOPMENT OF THE MARYLAND COAL FIELD.

The region of the Big or Elk Garden bed in the Georges Creek and Frostburg districts was one of the earliest of the northern bituminous basins to be worked. Almost from the time of the discovery of coal near Frostburg in 1804 coal has been extracted from this rich deposit, though it was not until 1830 that the first eastern shipments were made by means of barges on the Potomac River. With the construction of the Baltimore and Ohio Railroad in 1842 the commercial exploitation of the coal began rapidly to develop, and its growth was further promoted by the completion of the Chesapeake and Ohio

Canal in 1850. Since that time the output has rapidly increased, over 4,807,000 tons being marketed in 1899.

The production and values of the Maryland coals for the years 1891-1900 are shown in the accompanying table:

Amount and value of coal produced in Maryland, 1891-1900.

Year.	Short tons.	Value.
1891	3,820,239	$3,082,515
1892	3,419,962	3,063,580
1893	3,716,041	3,267,317
1894	3,501,428	2,687,270
1895	3,915,585	3,160,592
1896	4,143,936	3,299,928
1897	4,442,128	3,363,996
1898	4,674,884	3,532,257
1899	4,807,396	3,667,056
1900	4,024,688	3,927,381

The overwhelmingly greater portion of this Maryland coal production is derived from the Big (Elk Garden) coal, the major portion of the balance being obtained from the Davis and the Thomas beds along the Upper Potomac, in Garrett County. A small amount is mined for shipment from the supposed representative of the Davis bed in the Youghiogheny basin along the line of the Baltimore and Ohio Railroad.

The local great predominance of the Big bed has led to the general neglect of the "thin beds" of the Allegheny and Conemaugh formations, while the vast geographic advantage in position of the Big bed in the eastern basin is responsible for the relative lack of interest in the thin beds in the Salisbury and Youghiogheny basins. However, the expansion of the market, combined with the limited area of the Big bed, large portions of which are now exhausted, have caused the establishment of a considerable number of mines, especially in the Upper Potomac Valley and in the lower portion of the Georges Creek district. The increase of operations is particularly noticeable along the lines of the West Virginia Central toward the head of the basin, where the Davis and the Thomas coals are in fine condition. The Upper Potomac and Elk Garden districts are at present the regions of greatest activity in mining the thin beds. However, as the various mines now operating in the Big bed are becoming worked out, attention is coming more and more to be paid to the examination and occasional development of the lower beds, often with the utilization of the old apparatus.

The somewhat incomplete investigation of the Allegheny coals in the two western basins of the Maryland region appears to indicate the southward continuity in thickness and quality of the beds of this formation in Somerset County, Pa.

The remaining areas of the Big bed, which is almost exhausted in the lower Georges Creek district, are rapidly being reduced to the more inaccessible or deeply covered territory about Frostburg. The further reduction of this available territory can hardly fail to greatly accelerate the development of the thin coals, not only in all districts of the Potomac basin, but also extensively in the Salisbury and Youghiogheny basins.

The output of the northern half alone of the Potomac basin now approximates 4,000,000 tons annually. Several of the mines report a capacity amounting to about 1,200 tons daily in excess of their output. That this unused capacity falls on the whole far short of the prospective reduction by exhaustion of company territory is evidenced to some extent by the number of new mines recently opened or now in prospect.

At most of the Maryland coal mines the operation is by the "room and pillar" method. Not more than four slopes are reported. No shafts are at present in operation. Tail-rope haulage is used to some extent. There are relatively few installations of machine mining, the introduction of machines representating the pick or puncher type dating from 1899. The 10 machines in use produced 138,014 short tons in 1900.

The wage scale of mining now in operation is 55 cents per ton, run of mine, for hand work, or 40 cents for machine. The cost per ton of the coal f. o. b. cars at the mine ranges, as reported by the operators, from 67½ cents to $1, the average being about 81 cents.

DISTRIBUTION OF THE PRODUCT.

The greater part of the steam coal mined in western Maryland finds its way to the factories and shops of the Eastern States north of North Carolina, though a small proportion is distributed in the Middle and Western States. The chief points of destination are Washington, Baltimore, Philadelphia, and Staten Island or South Amboy. A large percentage is devoted to marine consumption, though a considerable portion appears to be consigned for export. The purer grades, which are especially suited for forge and smithing use, have a very wide distribution, including the Eastern States, portions of Canada, the West Indies, Mexico, and the northern United States as far west as the Rocky Mountains.

The middle and western basins are handicapped not only by their more remote geographical positions with reference to the tide-water market, but by the lack of railway facilities, which are confined for the most part to the main line of the Baltimore and Ohio Railroad. The Potomac basin, the source of the vast proportion of the output, is exceptionally well supplied with transportation media, the Upper

Potomac districts being served by the West Virginia Central, the central district by the Baltimore and Ohio and the West Virginia Central, while the northern or Georges Creek and Frostburg districts are traversed by the Cumberland and Pennsylvania and the Georges Creek and Cumberland railroads. All the railway lines converge at Cumberland, whence coal is taken by the Baltimore and Ohio Railroad, the Pennsylvania system, or the Chesapeake and Ohio Canal.

The cost of transportation appears to vary somewhat according to the starting point and route, but the rate from the Georges Creek district is reported as \$1.45 per ton for track delivery to Washington, Baltimore, and Philadelphia; or \$1.18 to Baltimore, \$1.25 to Philadelphia, and \$1.55 to South Amboy for water shipments.

THE BITUMINOUS COAL FIELD OF OHIO.

By Robert M. Haseltine.

AREA AND SUBDIVISIONS OF THE COAL MEASURES.

The area in this State underlain by coal has been estimated at 12,000 square miles, and it occupies either wholly or in part the thirty counties forming the southeastern portion of the State.

The Coal Measures of this region are divided into five groups, with average thickness as follows:

Coal Measures of southeastern Ohio.

	Feet.
5. Upper Barren measures	950
4. Upper Coal measures	250
3. Lower Barren measures	500
2. Lower Coal measures	600
1. Pottsville conglomerate	300

There are at least 16 coal beds present in the series within the State. Of this number, 6 are important, and have been largely developed, while 10 afford mines of small production, or are operated merely for the local trade. The productive beds are: The Block (Sharon) coal, No. 1; Wellston, No. 2; Lower Kittanning, No. 5; Middle Kittanning, No. 6; Upper Freeport, No. 7; and Pittsburg, No. 8. The northern and western boundaries, as well as the inferred extent of these several beds, will be seen by referring to the accompanying map (Pl. XI).

The coals of these several beds differ somewhat widely in character and in adaptability to the varied requirements in the fuel markets.

CHARACTER OF THE COAL.

Coal No. 1, or the Block coal, which occurs chiefly in the northeastern portion of the State, was probably formed in irregular depressions in the previously deposited conglomerate that forms the base of the Upper Carboniferous. Along the western margin of the Coal Measures, however, this coal is separated from the conglomerate by about 50 feet of shale.

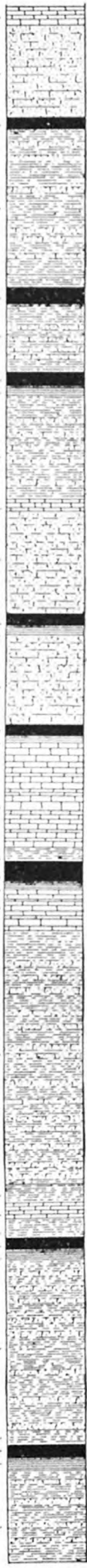
In the northern portion of the field the coal usually has well-defined joints, coming from the mine in large blocks, and is remarkable for its strength and fiber. Southward, in Summit and Stark counties, it becomes more bituminous than in Trumbull and Mahoning, and breaks more irregularly, having less of the block character. Also, in the two latter counties, the lamination is more pronounced. In the eastern portion of the field the top layers have a long grain, are lean in quality, and are called slabs, while the lower bench appears in large, regular cubes. This bed furnishes a good steam coal and a very desirable fuel for domestic purposes. Its chief usefulness is in its adaptability to the making of pig iron, for, owing to its purity, it can be used in its raw state in the blast furnace. It was this coal which supplanted charcoal in the early established blast furnaces of the State. The coal is dry burning, and hence noncoking. The composition of the coal from this bed is shown by the average results of 13 analyses given in the table on page 221. Of these, 7 are from mines in Trumbull, Summit, and Portage counties, and the remaining 6 from mines in Trumbull, Mahoning, Tuscarawas, and Stark counties.

The field was developed early. The first shipment of which we have a record was in 1828, when Henry Newberry, of Tallmadge, Summit County, sent a consignment to Cleveland, Ohio. The second recorded attempt occurred about 1841, when the late Governor Tod sent a canal-boat load from his Brier Hill mines at Youngstown to Cleveland to be used on the lake. It, like the first, met with an indifferent reception, and it was several years before the trade assumed any proportions. About this date Wilkinson and others attempted its use as fuel in their blast furnaces at Lowellsville, where it met with more favor, and its use for smelting iron became general. For more than twenty-five years the furnace men in this region used it exclusively in their business.

This coal was mined by hand labor. Two or three attempts at machine mining have been made, but, owing to the unevenness of the floor, they have proved unsatisfactory. It is to be regretted that within its known areas this valuable coal is largely exhausted.

The next coal of importance above the Block coal is known as No. 2, the Wellston bed, and the area within which it probably occurs in workable thickness is shown on the accompanying map (Pl. XI). It is found between the two divisions of the Massillon sandstone, and it is not likely to be mistaken for any other bed. Where both beds, No. 1 and No. 2, are present, the distance between them varies from 45 to 75 feet. Throughout northern Ohio it rarely attains a thickness of more than 2 feet, and is here known as the Rider vein. At Wellston, in Jackson County, it attains a thickness of 4 feet, and is the source from which this county for several years has led in annual production.

At Jackson Court-House this coal is but 2½ feet in thickness, and gradually increases toward Wellston. It is a free, open-burning, noncoking coal, and is used in its raw state in the local blast furnaces. Its popularity as a domestic coal is unequaled in the Ohio markets by any other coal with which it comes into competition. At Jackson the



	Strata.	Feet.	Local Name.
Dunkard.	Limestone	7.	
	Sandstone	40.	
	Coal No. 13	1-2.	
	Sandstone and shale	70.	
	Coal No. 12	1-6.	
	Sandstone and shale	20-40.	
Monongahela.	Coal No. 8*b* or 11	1½-4	Macksburg. Waynesburg.
	Fire clay	1.	
	Sandstone and shale	30.	
	Limestone	6.	
	Sandstone	45.	
	Coal No. 8*a* or 10	3-6	Meig Creek. Sewickley.
	Fire clay	3.	
	Sandstone	35-40.	
	Coal No. 9	2½	Redstone in Pennsylvania.
	Fire clay	½.	
	Limestone	30-70.	
	Black shale	2-10.	
	Coal No. 8	4-8.	Pittsburg.
	Fire clay	3.	
Conemaugh.	Limestone	4-30.	
	Shale and sandstone	110.	
	Shale	5-10.	
	Crinoidal limestone	2-8.	
	Shale	1-17.	
	Coal No. 7*b*	½-4	Norwich. Patriot.
	Fire clay	2.	
	Shale and sandstone	50-100.	
	Shale	2-10.	
	Coal No. 7 (*a*)	1-6	Grof. Stripe vein. Brush Creek.
	Fire clay	1.	
	Sandstone and shale	50	Mahoning.

	Strata.	Feet.	Local Name.
Allegheny.	Coal No. 7	0-5	Upper Freeport. Cambridge. Big vein. Waterloo.
	Fire clay	3.	
	Limestone	2-10.	
	Sandstone	0-50	Stillwell (often conglomerate).
	Gray shale	0-50.	
	Buff limestone	0-10.	
	Black band iron ore	0-14.	
	Fire clay	3-5.	
	Limestone	0-10.	
	Coal No. 6*b*	3-5	Lower Freeport. Hatcher. Steubenville. Whan.
	Shale and sandstone	40-50.	
	Coal No. 6*a*	0-6	Upper Kittanning (not mined in Ohio).
	Fire clay	3-5.	
	Sandstone	0-50.	
	Gray or black shale	5-50.	
	Coal No. 6	3-12	Hocking Valley. Straitsville. Middle Kittanning. Sheridan.
	Fire clay	3-5.	
	Limestone	2-8.	
	Gray or black shale	25-50.	
	Coal No. 5	2-5	Mineral Point. Lower Kittanning. Leetonia. New Castle.
	Fire clay	3-6.	
	Shale and sandstone	20-40.	
	Limestone	2-8	Gray ferriferous; Put- [nam Hill.
	Coal	1-7	Upper Clarion.
	Fire clay	2-12.	
	Sandstone	6.	
	Coal No. 4	2	Brookville.
Pottsville.	Shale and sandstone	10-60	Homeward. Piedmont.
	Coal No. 3*b*	3	Tionesta.
	Shale and sandstone	10-20.	
	Coal No. 3*a*	3	Bruce.
	Limestone, with iron ore	2-6.	Upper Mercer.
	Coal No. 3	3	Lower Mercer.
	Fire clay	5-15.	Flint Ridge cannel.
	Shale and sandstone	30-50	Upper Massillon.
	Coal No. 2	1-5	Wellston. Quakertown.
	Fire clay	1-3.	
	Shale	20-50.	
	Sandstone	20-80	Lower Massillon.
	Gray shale	5-40.	
	Coal No. 1	3-6	Brier Hill. Massillon. Jackson shaft.
	Fire clay	3-5.	
	Sandstone and shale	10-50.	
	Conglomerate		

VERTICAL SECTION SHOWING CARBONIFEROUS FORMATIONS IN OHIO.

coal contains only 2 per cent of ash. At Wellston, where it attains its highest development in thickness, the coal contains 5 per cent. The composition of the coal from this bed is shown by the results of analyses given in the table on page 221. No. 6 is the analysis of an average sample from 6 mines distributed throughout the field, and fairly represents the average composition of the coal.

This field was discovered in 1872, and its development began soon afterwards, reaching a maximum in 1899, when it produced 2,179,757 tons. As most of the mines have reached the limits of their territory, their output will henceforth gradually decrease. The Wellston coal finds a ready market throughout northwestern Ohio, eastern Indiana, the lake ports, and Michigan points, where it is used for railroad, manufacturing, and domestic purposes.

The next important coal above the Wellston is bed No. 5, or the Lower Kittanning, as it is more generally known throughout the field. It is from 15 to 25 feet above the ferriferous limestone, which is one of the most persistent and easily recognizable horizons in this region. This bed not only occupies a large portion of the coal field of Ohio, but that of Pennsylvania as well. Its area coincides with that of coal No. 6, the Middle Kittanning, as shown on the accompanying map (Pl. XI). In Ohio it is mined in almost every county in the Ohio coal field, from southern Mahoning on the north to the Hanging Rock region on the south. It is generally less than 3 feet thick, although at a few places, as at Mineral Point in Tuscarawas County, Zanesville in Muskingum County, and Newcastle in Lawrence County, it increases to 4 or 5 feet.

This bed is worthy of special mention on account of its coking qualities, as in fact it contains the only coal within the State which can be coked successfully. At Leetonia, Columbiana County, although less than 3 feet in thickness, it has for years supplied fuel for a blast furnace and rolling mill. In addition, it has met with good demand as a steam coal. Its value as a fuel will be seen from the analyses Nos. 7 to 9 in the accompanying table, page 221.

The coal has all been secured by pick mining. Owing to the thinness of the seam, machine mining has been regarded as impracticable. For this reason no large developments are expected in the near future. The coal usually finds a market for steam generating purposes at nearby points. The only exception is the amount consumed in the manufacture of coke in Columbiana County.

Coal No. 6, or the Middle Kittanning, like its associate, the Lower Kittanning, has a wide distribution. In Columbiana County it possesses less value than in any other county within the State in which it occupies an equal area. In the northern and central portions of the county it is less than 1 foot in thickness. Along the southern line, owing to its quality, it is extensively worked, although only between

20 and 30 inches in thickness. In Holmes County it is from 2½ to 3½ feet thick.

It is present over a considerable portion of Coshocton County, where its thickness ranges from 3 feet to 4 feet 10 inches. An average in five mines, distributed through the county, shows it to have an average thickness of 3 feet 8 inches. It underlies a portion of Muskingum County, and in the vicinity of Zanesville has an average thickness of about 3 feet 3 inches.

In northern Perry County it retains the general characteristics which are common in Muskingum County. At Shawnee it forms the great Hocking Valley seam. From there southward, with but few exceptional localities, throughout Perry, Athens, and Hocking counties, which is known to the trade as the Hocking Valley region, the regular benches increase in thickness. These, again, are reenforced by the Hocking Valley supplementary seam, which increases the bed to an aggregate thickness of from 8 to 13 feet. A portion of this, however, is rejected, so that not more than 10 feet in any instance is sent to the market.

The lamination of the coal is very pronounced. It mines in large blocks and withstands the rough usage incident to the lake trade, to which it is mostly diverted. It is a free, open-burning coal, and is well regarded as a steam fuel; it also is very popular for domestic uses. As a furnace coal it is not surpassed by any in the State. For the two latter purposes it is a rival of the block coal of the Mahoning and Tuscarawas valleys. With the exception of a small area along Little Raccoon Creek, in Gallia County, where it attains some prominence, the bed throughout Vinton, Gallia, and Lawrence counties has about the same character and value as in northern Perry and Muskingum and the counties in the northern portion of the field.

The composition of the coal from the Middle Kittanning bed is shown by analyses 10 to 13 in the accompanying table. Analysis No. 13 is of samples from 10 mines and represents the average composition of the coal in the Hocking Valley region.

For the last fifteen years the Hocking Valley has furnished from 32 to 38 per cent of the State's coal product. It is doubtful if the field will ever exceed the output of 1900, which amounted to 7,423,796 tons, or more than 38 per cent of the State's production.

The No. 7, or Upper Freeport, is rated as second in importance of the coal beds of the State. It no doubt originally extended over a much larger area than at present, and if it had a marginal fringe of thin coal like the Kittanning beds, this has been entirely removed by erosion. It occurs but a few feet below the coarse conglomerate of the Mahoning sandstone. It is probable that the strong currents which brought in the sand carried away much of the recently deposited coal, thus giving rise to large wants in the field.

It has been largely developed at Salineville, Sherrodsville, and Cambridge. Other large fields are known to exist in Muskingum County, near Caldwell in Noble County, in portions of Perry, and in the Waterloo field in Gallia and Lawrence counties. When fully developed it is from 5 feet 4 inches to 6 feet 9 inches thick. It is usually incumbered with two bands, although three appear in some localities. In addition it possesses a number of thin slate partings in the form of binders. It is a well-jointed coal, and slacks moderately. The slack, aside from the presence of sulphur, makes a fairly good coke.

The quality of the coal from the Upper Freeport bed is shown by analyses Nos. 14 to 19 in the accompanying table, page 221.

From the earliest development until 1893, when mining machines were installed in the Trail Run mine, in Guernsey County, the coal was produced by pick mining. The adaptability of the Upper Freeport bed to machine mining was at once apparent, and the installation of machines became general, so that at the close of the year 1900 there were 45 machines in use in 16 mines opened on this bed. During the early development the mines were universally worked on the single-entry system. This may be true of some of the small mines at this time, but all of the modern mines are worked on the double-entry system.

This is rated as one of the best steam coals in the State, and the product is consumed chiefly by the railroads. A small proportion, however, is used for fuel in local rolling mills and manufactories.

Coal No. 8, or the Pittsburg bed, if not the most important coal within the State, is the most important of the Upper Coal Measures, of which it forms the base.

The bed occurs in the southeastern portion of the State and, as will be seen by the accompanying map (Pl. XI), occupies the whole or a part of the counties of Jefferson, Harrison, Belmont, Guernsey, Athens, and Meigs. In the last-named county the coal outcrops under a heavy ledge of sandstone on the north bank of the Ohio River, where its presence has been plainly visible to the navigators of that stream for more than a century. This, no doubt, led to its early development, the exact date of which is not definitely settled.

The Pittsburg bed occurs about 300 feet above the Ames or Crinoidal limestone, and about 100 feet below Coal No. 9, or the Meigs Creek bed. The coal rests upon a bed of fire clay, beneath which is a bed of non-fossiliferous limestone. Several characteristic partings occur in this bed, which render its identification comparatively easy wherever it is exposed. The first parting is a thin black slate, which appears about 1 foot from the bottom. The second occurs about the middle of the bed, and consists of two thin bands of clay separated by from 1 to 5 inches of coal. When mined by hand, this is selected as the place to bear it in. The main seam is capped with a draw slate, from 10 to

20 inches thick, which usually falls as soon as the coal has been removed. This is the greatest peril and expense that menaces the miner in working this bed. Above this draw slate there occurs a vein of inferior coal, from 1 to 3 feet thick, which forms the permanent roof of the mine.

The main seam, or the portion considered merchantable, is generally from 4 to 6 feet thick.

In Athens County the bed presents a somewhat unusual form, as will be observed by the six sections in the accompanying table:

Sections of Pittsburg bed in Athens County.

	1.		2.		3.		4.		5.		6.	
	Ft.	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Coal	0	22	0	25	0	36	0	11	0	5	0	20
Slate	([a])		0	8	0	16	([a])		0	12	([a])	
Coal	0	28	0	4	....		0	41	0	8	0	24
Slate	0	7	0	12	0	12	0	12	([a])		0	12
Coal	0	3	0	8	0	18	0	4½	....		0	4
Slate	....		([a])		....		....		....		([a])	
Coal	([b])		([b])		....		0	7½	....		0	12
Clay	0	12	([b])		....		([a])		....		([a])	
Coal	0	12	0	22	0	19	0	22	0	24	0	23
Slate	....		([a])		....		....		....		....	
Coal	0	36	0	6	0	11	0	9½	0	8	0	8
Total	10	00	7	1	9	4	8	11½	4	11	8	7

[a] Streak. [b] Wanting.

The composition of the coal from the Pittsburg bed is shown by analyses Nos. 22–25 in the accompanying table, page 221.

Several attempts have been made to manufacture this coal into coke, all of which have been discontinued. This bed must be relied upon to furnish the major part of the State's coal product during the present century, as the other beds have been greatly depleted during the latter half of the century which has just closed.

COMPOSITION OF OHIO COALS.

The quality of the coals from this field is shown by the accompanying chemical analyses, which have been selected from the best sources available and are so arranged as to facilitate comparison between the several productive beds. The fuel ratios show a comparatively small range, considering the size of the field and the number of beds worked.

Analyses of Ohio coals.

No.	Locality.	Name of coal.	Number of analyses.	Moisture.	Volatile combustible matter.	Fixed carbon.	Ash.	Sulphur.	Fuel ratio.	Calorific value—B. T. U.
[a]1	Trumbull, Summit, and Portage counties.	No. 1. Block coal..	7	4.93	37.33	52.15	5.22	1.34	1.40	....
[b]2	Trumbull, Mahoning, Tuscarawas, and Stark counties.	.....do.............	6	4.13	34.37	58.20	1.94	0.80	1.69	....
[c]3	Wellston.............	No. 2. Wellston bed.	1	8.57	36.40	51.39	3.64	0.06	1.41	....
[c]4	Coalton..............	.....do.............	1	7.46	36.40	54.97	1.17	0.68	1.51	....
[c]5	Lick Township.......	.....do.............	1	8.89	34.03	52.60	4.48	0.96	1.55	....
[c]6	Six mines throughout the field.	.....do.............	1	8.17	35.79	52.78	3.25	......	1.47	12,578
7	Leetonia	No. 5. Lower Kittanning.	1	3.60	37.86	56.14	2.40	0.82	1.48	....
8	Washingtonville	.....do.............	1	4.37	35.50	57.91	2.22	0.69	1.63	....
9	Newcastle............	.....do.............	1	5.19	41.86	47.69	5.26	1.40	1.14	....
10	Holmes County.......	No. 6. Middle Kittanning.	1	4.51	44.86	44.55	6.08	4.68	0.99	12,000
11	Coshocton County....	.....do.............	1	4.61	44.73	47.83	2.83	2.28	1.07	....
12	.....do..............	.....do.............	1	4.41	43.98	46.38	5.73	3.99	1.05	....
13	Hocking Valley, 10 mines.	.....do.............	1	5.93	36.48	52.41	5.13	1.09	1.44	12,387
[d]14	State line, Columbiana County.	No. 7. Upper Freeport.	....	2.10	39.37	53.46	5.07	2.87	1.36	12,594
[d]15	Dell Ray, Carroll County.	.....do.............	....	4.20	37.01	51.64	7.15	3.09	1.39	....
[d]16	Sherrodsville, Carroll County.	.....do.............	....	4.20	39.32	52.58	3.90	1.92	1.34	....
[d]17	Cambridge (5 samples).	.....do.............	....	3.87	36.76	53.75	5.64	1.67	1.46	12,758
[d]18	Waterloo field (3 samples).	.....do.............	....	6.85	36.58	49.73	6.84	0.76	1.36	....
[d]19	Salineville (2 samples).	.....do.............	....	2.79	38.28	53.26	5.66	2.05	1.39	13,088
[e]20	Jefferson County.....	No. 8. Pittsburg bed.	1	1.83	40.06	50.09	7.02	3.31	1.25	....
[f]21	Harrison County.....	.....do.............	2	2.91	40.42	49.42	7.25	3.66	1.22	....
[g]22	Belmont County (4 samples).	.....do.............	....	1.89	41.75	48.27	8.08	4.24	1.16	....
[h]23	Belmont County......	No. 8. Pittsburg bed (roof coal).	....	1.93	40.54	45.80	11.73	6.33	1.13	....
[h]24	Meigs County (10 samples).	No. 8. Pittsburg bed.	....	4.81	38.60	50.05	6.51	1.42	1.30	....
25	Athens County (4 samples).	.....do.............	....	4.85	40.39	47.60	7.14	4.22	1.18	....

[a] Ohio Geological Survey, Vol. V, p. 1106.
[b] Ohio Geological Survey, Vol. II, p. 135.
[c] N. W. Lord, A. A. A. S., 1878.
[d] N. W. Lord, Trans. A. I. M. E., Vol. XXVII, 1897, p. 259.
[e] Ohio Geological Survey, Vol. VI, p. 599.
[f] Ohio Geological Survey, Vol. VI, p. 626.
[g] Ohio Geological Survey, Vol. VI, p. 605.
[h] Ohio Geological Survey, Vol. VI, p. 638.

METHODS OF MINING.

The early mine managers were reared in a section where the mines were conducted upon the single-entry system and hence this system was universally established throughout the State. This system of mining prevailed until early in the eighties, when the double-entry system was introduced into some of the larger mines. There are still many mines in the State conducted on the single-entry system. These are confined chiefly to the thinner beds. By far the greater number of mines, however, are operated on the double-entry system, and in a few instances the three-entry system has been adopted.

Up to the year 1877 all coal was produced by pick mining. It was during that year that the first economical mining machine within the State, and perhaps within the country, was introduced. It was a breast machine of the rotary bar type, the design of Francis M. Leichner, of Columbus, Ohio, and was installed at a mine at New Straitsville, in the Hocking Valley. This machine was the nucleus around which the great Jeffrey Manufacturing Company has since grown.

During the spring of 1881, J. W. Harrison introduced a machine of the reciprocating pattern in the W. B. Brooks mine, near Nelsonville. Both types of machine continued to be operated in a small way up to the year 1889. Their use at this time was confined to 13 mines. These were distributed over 7 counties, in 4 of which there was but one plant each. The total production of machine-mined coal during that year was 900,000 tons. It was during this year that electric power was successfully applied to machine mining. From this time on machines have continued to displace the skilled miner, until at the close of the year 1900 there were 358 mining machines employed in 94 mines. These were distributed over 15 counties. From this source there originated 6,292,429 tons of coal, or nearly 32½ per cent of the State's output.

Machines are being operated in 3 mines in the No. 1 or Block bed, in 7 mines opened in the Wellston or No. 2; 48 in the Middle Kittanning or No. 6; 1 in No. 6b or the Hatcher bed; 22 working in the Upper Freeport; and 13 operating in the Pittsburg or No. 8 bed. The early development of machine mining occurred in the Hocking Valley, where the great thickness of the coal attracted the attention of inventors, and it is in this field chiefly that the evolution of mining machines has taken place. At the close of the century there were in this region 197 machines. These were installed in 50 mines, and in 1900 produced a large proportion of the 6,292,429 tons of machine-mined coal. In fact all mines of importance in this district now use mining machines.

Prior to the introduction of machine mining, the labor in and about the mines was performed principally by skilled miners who came originally from England, Wales, Scotland, and Germany. The mining machines dispensed with the necessity of employing skilled miners, and the old miners have gradually been supplanted by natives of Hungary, Slavonia, Poland, and Italy, and southern European countries. The adoption of the mining machine also necessitated a greater subdivision of the labor in and about the mines.

The labor and skill required to mine a ton of coal in different parts of the field and in different beds varies somewhat widely. With a view of equalizing these differences, the State has been subdivided into several districts, and a scale of wages has been arranged for each. The scale paid in the Hocking Valley for the year 1901–02 is as follows:

Mining scale for Hocking Valley, April 1, 1901, to April 1, 1902.

Pick mining rate:		
Screened lump coal	per ton	\$0.80
Run of mine, $\frac{5}{7}$ lump price	do	.57½
Dry entries	per yard	2.00
Break-throughs in entries	do	2.00
Break-throughs in rooms	do	1.39
Room turning	do	3.03
Timbermen	per day	2.28
Track layers	do	2.28
Track layers' helpers	do	2.10
Pipemen	do	2.22
Trappers	do	1.00
Cagers, drivers, machine haulers, water haulers, and all other inside day labor	per day	2.10
Dumpers and trimmers	do	2.10

Couplers, greasers, slack haulers, firemen, engineers, carpenters, blacksmiths, cleaners, hostlers, and other outside day labor; special prices according to nature of work.

Cutting:		
By Jeffrey styles of machine, in rooms	per ton	\$0.09
By Jeffrey styles of machine, in entries	do	.12¼
By punching machine, in rooms	do	.13½
By punching machine, in entries	do	.14¾
Loading:		
In rooms	do	.41
In rooms, with hand drilling	do	.44
In entries	do	.51½
In entries, with hand drilling	do	.54½
Break-throughs in rooms	do	.48¼
Break-throughs in rooms, with hand drilling	do	.51¼
Drilling by hand	do	.03
Drilling by machine	do	.02¼

The above is the standard or basing scale for Ohio, and the scales for other districts of the State differ from it only in minor details determined by the greater or less skill and labor required to mine a given amount of coal.

The average cost per ton in the cars in the various districts is approximately as follows:

Average cost per ton in the cars in various Ohio fields.

Massillon and Northeastern field	$1.23
Wellston field	1.21
Hocking field	.93
Upper Freeport field	.89
Tuscarawas field	1.06
Pittsburg field	.88½
Average	1.03½

As to the prospective development, the reports indicate that the product of about 30 per cent of the mines will be increased, and that 45 per cent have reached their maximum capacity. The condition of the remaining 25 per cent is not known.

The returns would indicate that the capacity of the mines was not reached during the year. The reports from 25 of the 30 coal-producing counties of the State show an output which varies from 8 to 68 per cent less than the estimated maximum capacity of the mines. The average excess of capacity over production in these 25 counties amounted to about 26 per cent. The State's output for 1900 was 18,988,150 tons; hence, had the mines been operated to their full capacity during the time that they were in operation the year's production would have been about 22,825,000 tons.

DISTRIBUTION AND MARKETS.

The Ohio coal is widely distributed. The Block, or No. 1, originating in the Massillon field and the northeastern part of the State, is very popular as a domestic grate coal, and for this purpose, in addition to supplying the local markets, it is shipped to Toledo, Buffalo, Cleveland, Chicago, points in southern Michigan, New York City, and into Canada.

The Wellston seam, or No. 2, is also popular as a domestic fuel, and finds a ready market in all of western Ohio, northeastern Indiana, Toledo, Detroit, Chicago, Michigan, and northwestern points, over portions of Illinois and Iowa, and as far west as Omaha, Nebr.

The Lower Kittanning, owing to its purity, is rated as a superior steam coal, and as such it is largely used by the railroads. It also has a wide domestic market, and is shipped to Cleveland, Toledo, and other cities. From Newcastle and other points in Lawrence County it is sent by water to Ohio River markets, as well as by rail into Indiana and Michigan.

The Middle Kittanning, which is mined more or less throughout the Ohio field, attains its distinction in the Hocking Valley district, from which it is shipped to Columbus and local points, to Cleveland, Cincinnati, Toledo, Detroit, Chicago, northern Indiana, Michigan, and the several lake ports. From the latter it is distributed to the northwestern lake ports and points in western Ontario, Canada. It is reported as being shipped as far west as Nebraska.

The Upper Freeport, or No. 7, is regarded as a fine fuel for manufacturing purposes, and as such is sent to Cleveland, Detroit, and other manufacturing cities in the West and Northwest. As a steam coal it has but few equals, and is largely used by the Pennsylvania, Erie, Baltimore and Ohio, and other trunk line railroads.

The Pittsburg, or No. 8, coal, like the Middle Kittanning, is also a desirable coal for long distance transportation. It is extensively used for railroad fuel, wherever mined. It is also extensively shipped to Cleveland and other lake ports, from which it is transported by vessel to the Northwest. Large quantities are conveyed to Chicago, points in Michigan, to the Grand Trunk Railroad, Toronto, and other Canadian points. From Pomeroy and the river mines it is shipped in barges to points on the Ohio and Mississippi rivers as far south as New Orleans.

The freight rates to the principal markets are set forth in the accompanying table.

Freight rates on coal from the Ohio field.

From—	To—											
	Columbus.	Cleveland.	Toledo.	Lake Erie ports.	Detroit.	Fort Wayne.	Indianapolis.	Logansport.	Chicago.	Mississippi River for points in Iowa.	Toronto.	Ontario.
Massillon:	*Cts.*	*Cts.*	*Cts.*	*Cts.*								
Stark County	....	60	65	.....	$0.80	......	......	......	$1.35	......	$1.65	$1.60
Middle district:												
Wayne County Medina County Summit County Portage County Tuscarawas County Carroll County Columbiana County	...	60	80	60	.95	......	......	......	......	......	......	......
Cambridge:												
Guernsey County Noble County	65	80	90	90	1.05	......	......	......	1.60	......	......	......
Belmont:												
Harrison County Jefferson County	65	80	90	90	1.05	......	......	......	1.60	......	1.90	1.85
Muskingum County	55	80	90	.....	1.05	......	......	......	......	......	......	......
Hocking district:												
Coshocton County	55	65	80	.....	.95	......	......	......	......	......	......	......
Athens County Hocking County Perry County Morgan County	65	90	90	90	1.05	......	......	......	1.60	$2.05	1.90	1.85
Wellston	65	90	90	90	1.05	$1.25	$1.20	$1.40	1.60	......	......	......
Pomeroy, Southwestern field:[a]												
Lawrence Scioto Gallia Vinton	65	90	90	90	1.05	......	......	......	1.60	......	......	......

[a] Operators own their own steamboats and barges and pay for the towing only.

THE SOUTHERN APPALACHIAN COAL FIELD

BY

CHARLES WILLARD HAYES

CONTENTS.

ILLUSTRATIONS.

THE SOUTHERN APPALACHIAN COAL FIELD.

By Charles Willard Hayes.

GEOGRAPHIC RELATIONS.

The Appalachian coal field extends from a point near the northern boundary of Pennsylvania southwestward to near the center of Alabama. For the purposes of the present report it has been divided approximately along the line of the thirty-seventh parallel into the Northern and Southern Appalachian fields. While this subdivision is somewhat arbitrary, since the field is essentially a unit throughout its entire extent, it is desirable, both for convenience of treatment and because the character of the coal-bearing formations and of the coals themselves and the conditions of development undergo a more or less decided change along this line. One important difference is that from the Northern field the coal goes east and northeast to the seaboard, while from the Southern it goes southeast and south.

BOUNDARIES OF THE SOUTHERN APPALACHIAN COAL FIELD.

This field includes portions of Kentucky, Tennessee, Georgia, and Alabama. It coincides practically with the Cumberland Plateau and its outliers, Walden Ridge, Sand Mountain, Lookout Mountain, Blount Mountain, etc. Its eastern boundary is generally a straight line, for the most part a regular escarpment facing upon the Appalachian Valley, while its western boundary is an extremely irregular line coinciding with the deeply dissected sinuous western margin of the Cumberland Plateau. Its northern boundary is just north of the southern row of counties in Kentucky. Its southern margin is irregular and indefinite, being a line along which the coal-bearing formations pass under the attenuated northern edge of the Mesozoic and later formations of the Gulf coastal plain.

From a breadth of about 50 miles at the Kentucky-Tennessee line, the field tapers gradually southward to its narrowest point, opposite Chattanooga, where it has been deeply dissected by the Tennessee

River and its tributaries, and has a breadth of less than 30 miles. From this point southward it increases in width to 85 miles at its southern edge in north-central Alabama.

SUBDIVISIONS OF THE FIELD.

The Southern Appalachian coal field is subdivided into three main districts. This subdivision is due ultimately to structural causes, but as these have resulted in certain centers of development, the immediate subdivision is based upon the commercial development of the coal. These three districts are the Jellico, Chattanooga, and Birmingham, each named from its most important town.

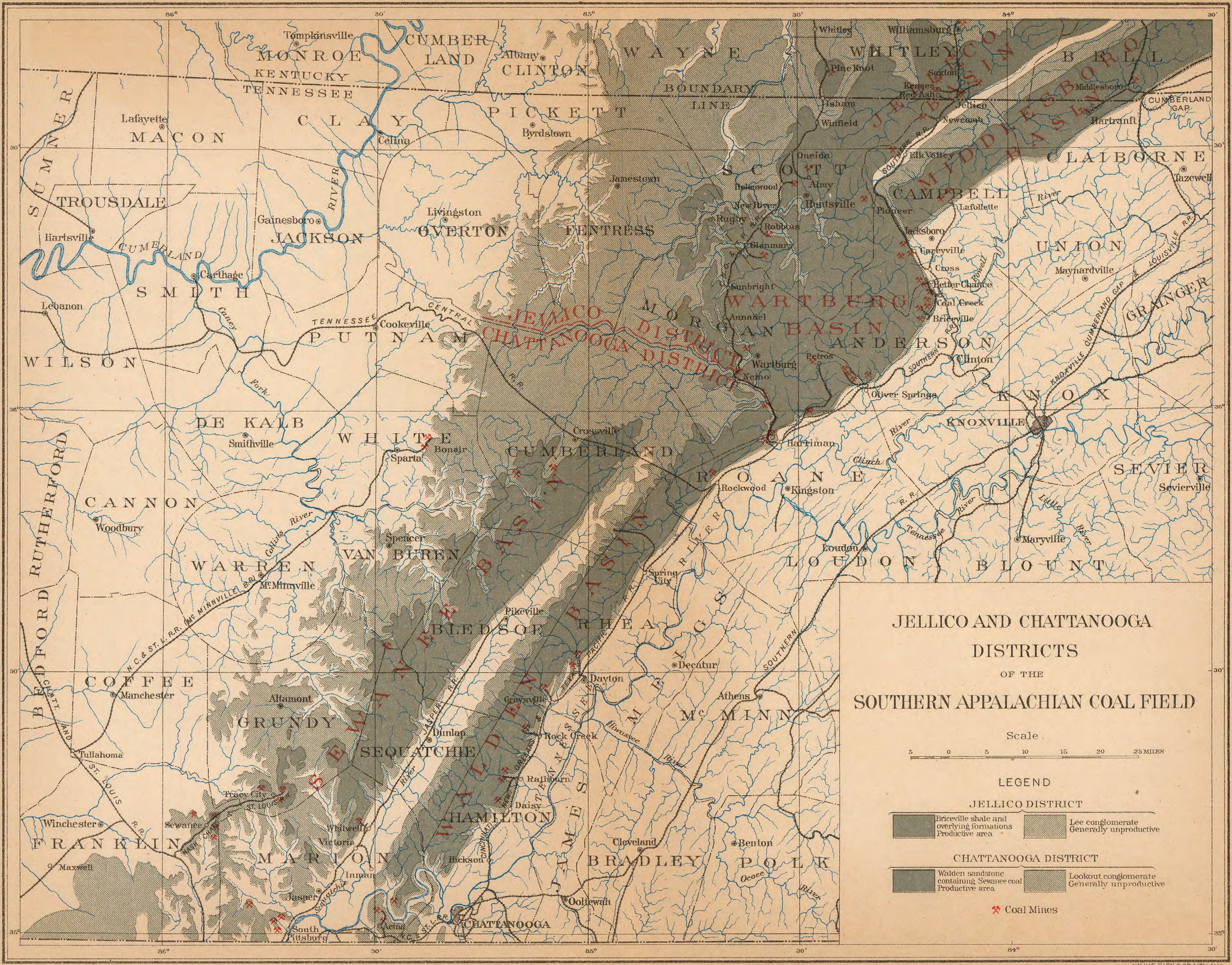
The Jellico district includes the northern portion of the field from the Emory River northward to a short distance beyond the Kentucky line. It is subdivided into the Jellico basin, the Wartburg or Brushy Mountain basin, and the Middlesboro basin.

The Chattanooga district includes the territory from the Emory River southward a short distance into northern Georgia and Alabama. It includes the Sewanee basin, which is a portion of the Cumberland Plateau, the Walden basin, separated from the Cumberland Plateau on the west by Sequatchie Valley, and the Lookout basin, which occupies the northern portion of the Lookout Mountain syncline.

The Birmingham district extends from a line connecting the southern point of Lookout Mountain and the great bend of the Tennessee River southwest to the southern limit of the coal field. It includes the Warrior basin, which is the southern portion of the Cumberland Plateau, the Blount Mountain basin, the Cahaba basin, and the Coosa basin. The Blount Mountain basin is a synclinal spur, connected at the north with the Walden syncline, and separated from the Warrior basin on the west by Murfrees Valley. The Cahaba and Coosa basins are long, narrow synclines, entirely isolated from the larger areas of coal-bearing formations to the west by still narrower anticlinal and fault valleys.

PROBABLE EXTENSIONS.

The eastern and western boundaries of the coal field are definite and well known, as the limits of the coal-bearing formation are distinct and easily determined. In these directions no extension of the coal field, as now represented on the maps, need be expected. The limit of the field toward the southwest is indefinite. The distance to which the coal-bearing strata extend beneath the cover of more recently deposited formations is not known. It is possible that they extend beneath the Mississippi embayment and were originally continuous with the coal fields of Arkansas and Indian Territory. This, however, is purely hypothetical, and for practical purposes they need not be



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considered beyond the western boundary of Alabama. The gradually increasing depth of the overlying gravels and clays renders the working of the coal more and more difficult toward the southwest, so that the depth of the cover practically limits the possible extension of the coal fields in this direction to an indefinite zone, probably a few miles in width beyond the margin of the field, as represented on the accompanying maps (Pls. XIII and XIV).

GEOLOGIC RELATIONS.

AGE OF THE COAL-BEARING ROCKS.

The coal-bearing formations of the Appalachian field are all of Carboniferous age. The type section of the Upper Carboniferous, or Coal Measures, is in Pennsylvania, and consists of five principal divisions with numerous minor subdivisions. The principal divisions are Dunkard Creek series, Monongahela series, Conemaugh series, Allegheny series, and Pottsville series. Most, if not all, of the rocks in the Southern Appalachian field correspond in age with the lowest subdivision of the Pennsylvania section, namely, the Pottsville. This subdivision in the bituminous field of western Pennsylvania has a thickness of about 300 feet (reaches a thickness of 1,200 feet in the anthracite field), but southward from the New and Kanawha rivers it shows a decided thickening. This thickening is very marked in the southern portion of the field, and it appears probable that the five or six thousand feet of coal-bearing rocks in the Birmingham district represent the same time interval as the few hundred feet in western Pennsylvania.

STRATIGRAPHY.

The coal-bearing strata of the Southern Appalachian field may be divided into two groups, which have been variously subdivided and named in different parts of the field.

The lower group consists of heavy beds of conglomerate or coarse sandstone, with more or less cross-bedded sandstone and shale below. This group is called the Lee conglomerate in the Jellico district, the Lookout conglomerate in the Chattanooga district, and the Millstone grit in the Birmingham district. This lower group, conglomerate, sandstone, and shale together, varies from a minimum of 50 feet to a possible maximum of 1,500 feet in the Wartburg basin. At some points there is an abrupt transition from the underlying Lower Carboniferous limestone to the Coal Measure sandstone and conglomerate, but more generally the transition is gradual through clay shales.

Beneath the main conglomerate bed there are over most of the field three coal horizons, though in some places there are as many as five, and in other places there is no coal at all. These coals are generally thin, sometimes being represented merely by a carbonaceous streak, and are always extremely variable in thickness, often passing from a maximum of 3 or 4 feet to as many inches within a few hundred yards. They can not, therefore, be worked profitably on a large scale except at a very few localities.

Wherever these subconglomerate beds are workable they yield a fuel superior to the higher coals for domestic and steaming purposes. Their superior quality enables them to be worked at some points in competition with the thicker coals of the same field.

Above the conglomerate group is a great series of shales, sandstones, and occasional conglomerate lenses, with numerous beds of coal. Throughout the entire field a rapid diminution in thickness is noticeable in passing from the eastern margin westward. Thus in the Jellico district the beds of this group decrease in thickness from 3,000 feet at the eastern margin to 1,750 feet within a distance of 50 miles. In the Chattanooga district the decrease is from 1,200 to 300 feet in about the same distance, and in the Birmingham district from 1,700 to 1,300 feet in 25 miles. This westward thinning of the formation suggests that these sediments were derived from land to the eastward, and that the surface on which deposition took place was depressed most rapidly where the material deposited was most abundant—that is, nearest the source of supply.

From the figures given above it will be noted that this upper group of coal-bearing rocks is much thicker at either end of the field than in the central portion. Thus on a section along the eastern margin of the field the group decreases from a maximum of nearly 6,000 feet in the Cahaba basin to 1,200 in the Walden basin, and then increases to 3,000 feet in the Wartburg basin. This extreme variation is due in part, at least, to the fact that only the lower members of the group occur in the central portion of the field, the upper members having been removed by erosion. In addition to this cause, however, there is probably a decided thickening of the formations both north and south, the present greater depth of the basins at the extremes of the field corresponding in part to an original more rapid deposition.

The larger part of the workable coal of the field occurs in this upper group of strata. The more important beds will be enumerated in the descriptions of the several basins. In a general way the coal shows an increase in number and thickness of beds corresponding to the increase in thickness of the inclosing formations. Hence the largest amount of coal to a given area is found along the eastern margin of the field.

STRUCTURE.

As the strata forming the coal field lie immediately west of the intensely folded belt which forms the great Appalachian Valley, they have been acted upon to some extent by the same forces which caused the Appalachian folding. In general the disturbance of the beds decreases from the eastern margin of the field westward, so that while the portion bordering the Appalachian Valley is in many places sharply folded and faulted the western margin is practically undisturbed, the beds occupying essentially the position in which they were formed and having a very gentle dip toward the east. The original extension of the coal-bearing formations is not known, but it is probable that these rocks were deposited in a long and relatively narrow trough which may have had a considerably greater extension toward the west, but whose eastern shore line was somewhere within the limits of the present Appalachian Valley, possibly quite near the present eastern margin of the coal field.

The original broad trough of deposition has been modified by the development of several sharp anticlinal folds parallel to its longer axis. From these anticlines the Coal Measures have since been eroded, forming sharp anticlinal valleys in which the underlying formations are exposed. The Coal Measures, on the other hand, occupy a series of long, shallow synclines which are relatively much broader than the intervening anticlines, and owing to the unsymmetrical form of the Appalachian folds the beds forming these synclinal troughs usually have a short, steep slope from their eastern sides westward and a long, gentle slope from their western sides eastward. Hence the axes or deepest portions of the troughs lie near their eastern margins.

As already stated, the western portion of the field is practically undisturbed, and the dips are perhaps only slightly greater than they were in the original trough of deposition. These structural features have an extremely important bearing on the economic development of the various basins, and a thorough understanding of them enables the engineer to locate and develop mines in such a manner as to utilize the inclination of the beds in securing natural drainage and economical haulage.

THE COAL.

JELLICO DISTRICT.

This district embraces that portion of the Southern Appalachian field lying north of the Emory River in Tennessee, together with the three southeastern counties in Kentucky—Knox, Whitley, and Bell. It includes three subdivisions or basins, viz: (1) Middlesboro, (2) Jellico, and (3) Wartburg. Their relative importance as indicated by number of beds mined and production is shown in the following table:

Table showing relative importance of basins in Jellico district.

Basin and county.	Number of coal beds worked.	Average thickness of coal in mines.	Production and value in 1900.		
			Quantity.	Value.	Average price per ton.
Jellico:		*Ft. in.*	*Short tons.*		
Whitley, Ky	3	2 8	673, 069	$773, 538	$1. 15
Knox, Ky	2	4 8	303, 969	279, 445	. 92
Campbell, Tenn	3	3 0	380, 291	478, 760	1. 26
Total			1, 357, 329	1, 531, 743	1. 13
Middlesboro:					
Bell, Ky	2	4 0	224, 500	223, 804	1. 00
Claiborne, Tenn	1	4 3	392, 699	411, 775	1. 05
Total			617, 199	635, 579	1. 03
Wartburg:					
Scott, Tenn	1	3 0	100, 338	110, 679	1. 10
Campbell, Tenn	1	3 6	122, 700	135, 131	1. 10
Anderson, Tenn	2	4 0	672, 752	718, 113	1. 07
Morgan, Tenn			388, 142	394, 122	1. 02
Total			1, 283, 932	1, 358, 045	1. 06

MIDDLESBORO BASIN.

This basin embraces portions of Campbell and Claiborne counties, Tenn., and Bell County, Ky. It is a long, narrow syncline extending in a northeast-southwest direction, separated from the Jellico basin on the northwest by a narrow anticline in which is the Pineville fault. It is separated from the Wartburg basin on the southwest by a transverse fault along which the lowermost beds of the Coal Measures are thrust over upon the higher beds toward the southwest.

The same syncline contains the Big Stone Gap coal basin in Virginia, and the coal beds are doubtless continuous from one to the other, but the two basins are separated by a considerable area within which the coal is entirely undeveloped and practically unknown.

Throughout the greater portion of the basin the strata are horizontal, but have gentle dips along the western and steep dips along the eastern margin. The upturned edges of the heavy conglomerate beds in the lower portion of the Coal Measures form a high rim about the basin so that in the interior the coal is accessible at only a few points where streams have cut notches in the rim. The northwestern rim is formed by Pine Mountain, the southwestern by Fork Mountain, and the southeastern by Cumberland Mountain. The latter is cut by Big Creek and Cumberland Gap, and the development of the coal in this basin is confined to the vicinity of these two gaps.

The basin contains several coal beds of workable thickness, but only one is at present mined. This is called locally the Bryson bed. It occurs in the Briceville shale about 250 feet above the top of the Lee conglomerate and probably at the same horizon as the Sewanee bed toward the southwest. The coal averages 4 feet and is very uniform in thickness and character over large areas. At the eastern margin of the basin it is mined by slopes, and a short distance away from the margin, where the strata are approximately horizontal, by drifts.

The basin contains a large amount of excellent coal, which can be mined cheaply when it is rendered accessible. Its present output of 617,199 tons is due almost entirely to development which has taken place since 1893.

JELLICO BASIN.

This basin includes portions of Scott and Campbell counties, Tenn., and of Whitley and Knox counties, Ky. For the most part its strata are practically horizontal, having a very slight dip from northwest to southeast, and being sharply upturned along the extreme southwestern margin. The coal-bearing formations are thinner than in the Middlesboro basin, and they show a rapid thinning toward the northwest. The number and thickness of the coal beds also decrease in the same direction. The coal-bearing formations of the upper group, as defined in the general description of the Southern Appalachian field, are confined to a belt along the southeastern margin of the basin, having been removed from the western portion by erosion.

The principal development has been in the eastern part of the basin along the Southern Railway, where the Jellico bed is worked. This probably corresponds to the Bryson bed in the Middlesboro basin and the Sewanee bed toward the southwest. It averages about 3 feet in thickness, as compared with 4 feet in other basins. Some mining has also been done on a higher bed, the Glenmary, farther west along the line of the Cincinnati Southern road. All the coal thus far developed is above drainage level and is mined entirely by drift.

WARTBURG BASIN.

This basin extends northeastward from Emory River and includes portions of Morgan, Anderson, and Scott counties, Tennessee. The upturned edges of the heavy conglomerate beds in the lower part of the Coal Measures form a high rim on the eastern margin of the basin as far north as Careyville. Within this rim, called Walden Ridge, is a narrow valley, beyond which extends a deeply dissected plateau. The larger part of the basin is drained by New River, a tributary of the Cumberland, while small streams flow southwest to the Emory and southeast to the Clinch, the tributaries of the Clinch cutting narrow gaps in the basin rim. The highest elevations in the Southern Appalachian coal field are found in this basin, the divides rising to altitudes of 3,000 feet or more, while the channel of New River is about 1,200 feet.

The principal development in the basin is along its eastern margin, where stream gaps, cut through the rim, render the coal accessible. Such gaps are cut by the Little Emory River, Indian, Poplar, and Coal creeks, and have determined the location of Oliver Springs, Briceville, and Coal Creek, the chief mining centers. Considerable mining is also being done in the western part of the basin along the line of the Cincinnati Southern Railroad.

Only two beds are at present worked in this basin. At Pioneer and Careyville the coal is in the Wartburg sandstone, while the more generally worked bed is lower down in the Briceville shale and probably corresponds to the Sewanee bed farther south. This bed averages about 4 feet in thickness at the eastern edge of the basin and decreases to a little over 3 in the western portion. In the vicinity of Briceville it is called the Coal Creek bed, at Oliver Springs the Poplar Creek, and in the western part of the basin the Glenmary bed.

In addition to the beds which are worked the basin contains a large number entirely undeveloped, some of which are of workable thickness and excellent quality. In the vicinity of Careyville no fewer than 15 beds occur, and in Cross Mountain over 30 are known.

As shown by the location of the mines on the map (Pl. XIII), the development of this basin has thus far been confined wholly to its margins. The drainage basin of New River is as yet untouched and it undoubtedly contains a large amount of excellent coal. All the coal thus far developed lies above drainage level and is mined by drifts.

CHATTANOOGA DISTRICT.

The Chattanooga district embraces small areas in northern Alabama and Georgia and a much larger area in Tennessee, extending northward to the Emory River. The district is divided longitudinally by the Sequatchie Valley, which separates the Walden Ridge syncline on the east from the Cumberland Plateau on the west.

It includes the Walden, Sewanee, and Lookout basins. Their relative importance as indicated by number of mines and production is shown on the accompanying table:

Table showing relative importance of basins in Chattanooga district.

Basin and county.	Number of mines operated.	Number of beds worked.	Average thickness of coal in mines.		Production and value, 1900.		
					Quantity.	Value.	Average price per ton.
Walden:			*Ft.*	*in.*	*Short tons.*		
Roane, Tenn	2	1	4	6	181,753	$227,191	$1.25
Rhea, Tenn	5	2	3	6	210,528	199,417	.95
Hamilton, Tenn	4	2	3	6	227,063	278,661	1.23
Marion, Tenn	2	1	2	2	37,884	64,168	1.64
Total					657,228	769,437	
Sewanee:							
Putnam, Tenn	1	1	3	0	7,275	8,002	1.10
Grundy, Tenn	17	1	3	6	336,198	450,247	1.25
Marion, Tenn	7	3	2	6	272,846	344,490	1.32
White, Tenn	3	2	2	6	210,505	252,606	1.20
Dade, Ga					315,557	370,022	1.17
Total					1,142,381	1,425,367	

WALDEN BASIN.

This is a long, narrow, unsymmetrical syncline, its strata having gentle dips along its western margin and being sharply upturned along its eastern margin. The basin contains two coal-bearing formations, the Lookout and the Walden. The first consists of heavy beds of conglomerate with sandstones and shales below in which there are usually from one to three beds of coal. These are workable in places, though not generally. Above the conglomerate are sandstones and shales and one very persistent and valuable coal bed, the Sewanee. The coal is generally above drainage level, and is worked by slopes and drifts. Within a narrow strip along the eastern margin of the basin the rocks are much disturbed, and mining is attended with considerable difficulty. In some cases the coal has been forced out into huge pockets, sometimes 80 to 100 feet in diameter. The coal in these pockets is always composed of small lens-shaped masses, whose surfaces are slickened by motion which has taken place within the bed. Beyond the extreme eastern margin of the basin the rocks are either horizontal or have a gentle and fairly uniform dip to the eastward. Most of the mining in this basin is on the Sewanee bed, although at some points a higher bed is worked and also at a few points the coal below the conglomerate is mined. The principal mines are at Rockwood, Dayton, Rock Creek, and Rathburn. The basin contains 13 mines, counting large and small, with a production in 1900 of 657,228 tons.

SEWANEE BASIN.

This basin lies west of the Sequatchie Valley, extending from the Alabama line northeastward a little more than half way across Tennessee. The strata are here practically horizontal except for a sharp upturn along the western edge of the Sequatchie Valley. The beds rise very gradually toward the northeast. A large proportion of the workable coal in this basin is in the Sewanee bed. The Walden sandstone, which contains this bed, has been largely removed by erosion from the southern and western portion of the Cumberland Plateau in Tennessee. In the vicinity of Sewanee only small patches of the bed occupy the highest portions of the plateau. In these the coal, which occurs under a light cover and is easily accessible, has been almost entirely worked out. Larger areas occur at Tracy City, where a considerable proportion of the workable coal has been mined. Thence northward the areas underlain by the bed increase in extent, forming a continuous belt to the head of the Sequatchie Valley.

The Sewanee coal has been extensively mined at Sewanee and Tracy City, which are on top of the plateau, and also at Whitwell. At the latter point the coal is reached by tunnels which cut through the upturned underlying strata and enter the coal bed at the bottom of the trough in which it lies. The mouth of the tunnel is 1,000 feet above the bottom of Sequatchie Valley, to which the coal is lowered by a gravity incline.

In this basin as elsewhere the coal underlying the Lookout conglomerate is variable in thickness. It has been worked at a few points in the vicinity of South Pittsburg, and extensively at Bon Air, on the northwestern margin of the basin.

LOOKOUT BASIN.

Lookout Mountain is a narrow, shallow syncline, the steep escarpments which surround its plateau-like summit being formed by the heavy beds of Lookout conglomerate. The Walden sandstone, which carries the Sewanee coal, has been removed from the greater part of its surface. At a few points the syncline deepens slightly, and the higher formation with its coal has been preserved. A small area of workable coal remains in the northern part of the syncline, in Walker County, Ga., about 15 miles south of Chattanooga. The Sewanee bed, here locally called the Durham bed, has a thickness of about 4 feet, and is extensively mined by the Durham Coal and Coke Company. About 30 per cent of the product is coked and the remainder is sold for steam fuel.

The Lookout coals have been opened at numerous points beneath the conglomerate escarpment, but have not been found sufficiently thick and regular for profitable working.

BIRMINGHAM DISTRICT.

As indicated above, the Birmingham district lies wholly within the State of Alabama, and embraces 4 subdivisions or basins, viz: (1) Coosa, (2) Cahaba, (3) Blount Mountains, and (4) Warrior. The relative importance of these basins, as indicated by area of workable coal, number of mines, and production, is shown in the following table:

Table showing relative importance of basins in Birmingham district.

Basin and county.	Area of workable coal.	Number of mines.	Number of openings.			Number of beds worked.	Average thickness of coal in mines.	Production and value at the mines.					
			Drift.	Slope.	Shaft.			1899.			1900.		
								Quantity.	Value.	Av. price.	Quantity.	Value.	Av. price.
							Ft. in.	*Short tons.*			*Short tons.*		
Coosa, St. Clair	345	2	......	4	......	2	3 7	52,252	$40,597	$0.82½	101,270	$119,140	$1.18
Cahaba:													
Bibb	......	5	......	6	......	2	5 6	912,263	1,041,484	1.14	964,785	1,183,072	1.23
Jefferson	......	2	......	3	......	1	5 6	42,528	48,732	1.15	71,230	82,600	1.16
Shelby	......	11	1	11	......	7	3 3	67,020	118,444	1.77	135,832	210,072	1.55
St. Clair	......	1	......	1	......	1	5 0	15,725	18,870	1.20	55,000	64,900	1.18
Total	270	19	1	21	......	11	......	1,037,536	1,227,530	......	1,226,847	1,540,644	......
Blount:													
Blount	......	......	......	......	......	......	......	......	......	......	......	......	......
St. Clair	......	......	......	......	......	......	......	......	......	......	......	......	......
Etowah	......	......	......	......	......	......	......	......	......	......	......	......	......
Total	100	......	......	......	......	......	......	......	......	......	......	......	......
Warrior:													
Blount	......	2	2	......	......	2	4 0	12,699	13,968	1.10	13,572	13,572	1.00
Cullman	......	2	3	......	......	1	4 9	8,000	12,000	1.50	50,000	7,500	1.50
Jefferson	......	47	48	31	1	6	4 8	4,835,668	5,247,182	1.09	5,184,066	6,062,393	1.17
Marion	......	1	3	......	......	1	2 6	17,395	18,775	1.08	37,058	46,225	1.25
Tuscaloosa	......	13	4	4	4	7	2 8	454,913	565,325	1.25	268,422	298,458	1.11
Walker	......	30	40	7	4	8	4 4	1,249,294	1,369,629	1.10	1,489,380	1,629,278	1.10
Winston	......	4	3	1	......	1	2 6	10,825	12,140	1.12	12,805	16,857	1.32
Total	2,625	99	103	43	9	26	......	6,588,794	7,239,019	......	7,055,303	8,074,283	......

COOSA BASIN.

The Coosa basin is the easternmost of the four which are included in the Birmingham district. It is about 40 miles in length and from 4 to 10 miles in breadth. Its western margin is formed by high ridges composed of the two heavy beds of conglomerate which occur near the base of the Coal Measures in this region. From the western margin the rocks have a general easterly dip nearly to the eastern margin, where they are sharply upturned and cut off by a fault, which brings the Lower Cambrian shales in contact with the coal. The basin is also cut by several faults which make acute angles with the axis of the syncline. A number of folds also cross the syncline transversely and separate it into several small basins, the greater portion of the coal-bearing rocks upon these cross folds having been eroded.

By reason of the folding and faulting which the rocks have undergone the coal is much disturbed and the workable beds are found in comparatively small isolated areas. These conditions render prospecting difficult, and the development of the coal is attended by unusual uncertainty and expense.

The table on p. 246 shows approximately the number and thickness of the seams which have been discovered. Some of these have been worked in the northern part of the basin, particularly in the Ragland, Fairview, and Coal City areas. The earliest coal mining in Alabama was done in this basin, a number of mines having been opened in the Ragland and Fairview areas between 1843 and 1847. The coal in general is somewhat softer than that in the Warrior field, and hence it does not bear transportation so well. It is, however, well adapted for coking, containing small percentages of sulphur and ash, and giving a good yield in coke of excellent quality. Considerable coke was at one time made in this region without ovens, the coal being simply piled up on the ground about a heap of stones and fired from the center.

At least 12 coal beds 36 inches and over in thickness are reported from this basin. The basin is at present worked at only two points, namely, at Ragland and Coal City. Owing to its complicated structure its development requires special skill on the part of the mining engineer, and because of lack of this the mines in this basin have not been able to compete with those in the less complicated fields to the west. According to Gibson's estimate the area underlain by workable coal is about 345 square miles, but no data are available for estimating the average aggregate thickness of the coal beds.

The following table[a] shows the names and thicknesses of the coal seams overlying the basal conglomerates, as determined by Gibson in the Fairview and Coal City basins:

[a] Report on the Coosa coal field, by A. M. Gibson: Geol. Surv. Alabama, 1895.

Coal seams overlying basal conglomerates in Fairview and Coal City basins.

	Ft.	in.
Hammond seam	4	4
Fourth conglomerate	500	0
Herbert seam	6	0
Coal City seam	4	0
Broken Arrow seam	3	8
Eureka seam	3	6
Gould seam	5	0
Hudson seam	4	0
Higginbotham seam	3	0
Fairview seam	4	4
Chapman seam	3	6
New Prospect seam	3	0
Corson seam	3	3
First and second conglomerates	1,000	0
Total thickness of section	5,750	0

CAHABA BASIN.

This lies next west of the Coosa basin, from which it is separated by a long, narrow strip of Devonian and Silurian rocks. It has a structure very similar to that of the Coosa basin; it is a long, narrow syncline, whose eastern edge is sharply upturned and, for the most part, cut off by a fault which brings the Cambrian and Silurian formations in contact with the Coal Measures. About midway of its length the syncline is interrupted by a cross fold which lifts the lower portion of the Coal Measures above drainage level, and from which the greater part of the coal-bearing rocks has been removed by erosion. Northeast of this cross fold the syncline is very regular, the beds having a uniform gentle dip toward the southeast nearly to the margin of the basin, where they are sharply upturned and cut off by the fault.

The sandstones and heavy conglomerates which occupy the lower portion of the Coal Measures form a series of parallel ridges throughout the western half of the syncline. The coal beds outcrop in parallel lines between these ridges, and in the lower land occupy the eastern part of the syncline, which is underlain by the upper and softer portions of the coal-bearing formations.

The southern half of the Cahaba basin is much less regular than the northern portion above described. It is broken up into a number of subordinate basins by transverse folds and by a faulted zone which branches from the eastern marginal fault and separates the southern half of the basin into two nearly equal portions. This faulted zone is merely a sharp, broken anticline, and its effect is to duplicate the outcrops of the coal beds, each of which, in the northern half of the basin, reaches the surface only along a single line. According to Squire, the total thickness of the Coal Measures in this basin is about 5,500 feet, which is slightly less than in the Coosa basin, although higher measures are found here, which have been removed by erosion from the basin to the east. The workable coal beds show an increase in number and thickness for the same reason. The total area of the Cahaba field underlain by workable coal is about 270 square miles, and the aggregate average thickness of workable coal is about 21 feet. The Cahaba field is divided by the transverse fold and the faulted zone above mentioned into three distinct basins, two of which are further subdivided into several subordinate basins by less pronounced transverse folds.

The Henryellen basin embraces the northern half of the Cahaba field. It contains 2 mines with a capacity of about 650 tons a day.

The Blocton basin, including also the minor Acton and Cahaba basins, occupies the southwestern portion of the field. It contains 7 mines with a capacity of somewhat over 6,000 tons a day.

The Montevallo basin occupies the southeastern portion of the field. It includes the following minor basins: Helena, Eureka, Dry Creek, Lolley, Montevallo, and Daily creeks. It contains 12 mines, most of which have a relatively small capacity, supplying a high-grade domestic fuel only.

In all of these basins, except along their eastern margins, the rocks have a rather steep southeasterly dip, averaging about 15°. They are also disturbed by many local folds and faults, and the methods of mining are quite different from those employed in undisturbed horizontal beds. When properly engineered and worked, however, the coal can be mined from these inclined beds with nearly the same facility as from horizontal beds of the same thickness.

BLOUNT MOUNTAIN BASIN.

Blount Mountain is a spur of the Cumberland Plateau extending southwestward between the Coosa Valley on the southeast and Murfrees Valley on the northwest. It has the form of a broad, gentle synclinal trough bounded by Straight Mountain on the northwest and Blount Mountain on the southeast. These are formed by the outcropping edges of the heavy beds of conglomerate near the base of the Coal Measures. This syncline forms a marked contrast to most of the synclines in the Appalachian region in that its steep dips are along the western margin and its gentle dips along the eastern margin. The reverse is generally the case.

According to Gibson 34 coal beds have been discovered in this basin, of which 16 are of workable thickness. Of these the Holt or Big seam is reported as having locally a thickness of 12½ feet. The field contains an area of approximately 100 square miles underlain by workable coal, and the average aggregate thickness of the beds over 2 feet is about 20 feet. It is practically undeveloped, only a few small mines having been operated intermittently for supplying local demands.

WARRIOR BASIN.

This is the most important of the several basins which are included in the Birmingham district. It contains a larger area of workable coal than the other three combined, and by reason of its structure the coal can be mined generally more economically than in the others.

The basin has a somewhat irregularly triangular shape. Its southeastern margin is formed by the sharp Murfrees Valley anticline from which the coal-bearing rocks have been removed by erosion. Its northern margin is formed by a broad transverse uplift which crosses the entire coal field and on which only the lower portions of the Coal Measures remain, the higher and more productive measures having been removed by erosion. The region occupied by this transverse uplift is not entirely devoid of workable coal, but its beds are so much less important than those higher up in the series that for present purposes they may be entirely neglected.

From this transverse uplift the rocks dip southward, bringing below the erosion surface successively higher beds down to the extreme southern margin of the basin. This northern border is, therefore, very irregular. The lower coals extend farthest north, occupying the highest land between the streams. These gradually pass below drainage southward, while the next higher beds come in on the hilltops and in turn pass below drainage toward the south. The highest coals, therefore, are confined to the hilltops in the southern portion of the basin.

The southwestern border is also indefinite. A few small remnants of Tertiary and Cretaceous clays and gravels are found on the hilltops near the center of the basin. These remnants suggest that these formations were at one time continuous, at least this far north, but their outer margins have been deeply dissected and only occasional fragments of the originally continuous beds remain. These patches of gravel and clay become more abundant toward the southwest and finally cover the whole surface except in the river channels. The larger streams remain upon the Coal Measures to the vicinity of Tuscaloosa, beyond which the whole of the surface is formed by these later deposits. Hence the southwestern margin of the coal basin is occupied by a zone in which the surface is formed partly by the underlying Coal Measures and partly by the overlying sand and gravel. The proportion of the former increases toward the northeast and the latter toward the southwest.

As already indicated, there is a marked decrease in thickness of the coal-bearing formations observable in passing westward from the Coosa to the Cahaba basin. Although exact correlations have not yet been made between the coal beds of the Cahaba and Warrior basins, the equivalence of various groups of coal beds has been determined with sufficient accuracy to indicate that the thinning is even more rapid between the Cahaba and Warrior basins than farther east. The coal-bearing rocks in the Cahaba basin down to the basal conglomerate have a thickness of something over 4,000 feet. Along the eastern margin of the Warrior basin the same formations have decreased to about 1,500 feet, and from this eastern margin the westward thinning is observable entirely across the basin. Accompanying the decrease in thickness of the coal-bearing formations there is a corresponding decrease in number and thickness of the coal beds themselves. The following table shows the number and aggregate thickness of the coal beds and of the inclosing formations, as determined by McCalley, in the eastern, central, and western portions of the Warrior basin:

Number and thickness of coal beds and inclosing strata in Warrior basin.

Name of group.	Total number coal beds.	Western margin of basin.			Center of basin, Warrior River section.			Eastern margin of basin.		
		Number workable beds.[a]	Aggregate average workable thickness.	Thickness of strata.	Number workable beds.	Aggregate average workable thickness.	Thickness of strata.	Number workable beds.	Aggregate average workable thickness.	Thickness of strata.
			Ft. in.	*Feet.*		*Ft. in.*	*Feet.*		*Ft. in.*	*Feet.*
Barren							100			50
Brookwood	5	1	2 3	95	4	7 6	100'	4	11 6	104
Interval				125			250			180
Gwin	2	2	2 6	40	2	2 2	30	2	3 4	35
Interval				155			160			165
Cobb	3	1	1 6	63	1	2 0	130	3	3 10	166
Interval				210			170			116
Pratt	5			138	3	8 6	156	4	14 4	145
Interval				210			260			340
Horse Creek	5			53	1	3 6	143	5	19 4	114
Interval				63			68			100
Black Creek	4	1	2 6	52	2	3 6	80	4	5 0	100
Total	24	5	8 9	1,204	13	24 0	1,647	20	57 0	1,695

[a] All beds are considered workable which at any point contain 2 feet or more of good coal. Their average thickness may be considerably under 2 feet.

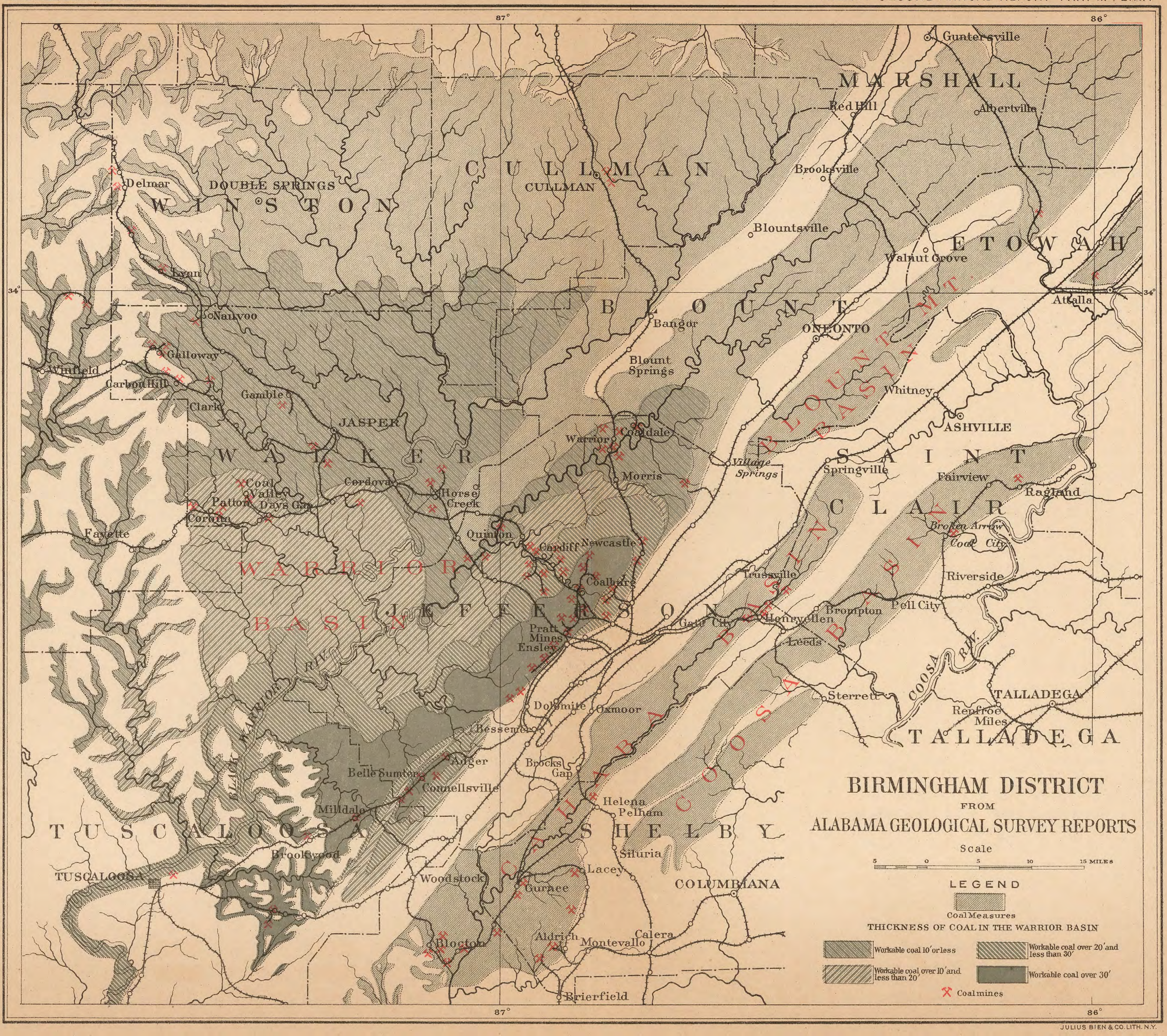
The names of the various coal beds which have thus far been developed on a commercial scale and their relative importance as indicated by the number of mines and production are shown in the following table. It will be noted that in 1899 the Pratt bed alone yielded 65 per cent of the total product of the basin. This enormous yield of nearly 4,000,000 tons came chiefly from the large mines along the eastern margin of the basin in the vicinity of Birmingham, where the Pratt bed alone is at present worked.

Production of coal beds in Warrior basin.

Name of coal bed.	Thickness.			Length of outcrop.	Area.	Mines operated, 1899.	Production, 1899.	Per cent of total production.
	Minimum.	Maximum.	Average.					
	Ft. in.	*Ft. in.*	*Ft. in.*	*Miles.*	*Sq. miles.*		*Short tons.*	
Milldale	0 8	4 0	2 0	....	150—	4	148,428	2
Johnson (Carter, Dafforn Hospital, Durie, etc.)	1 0	4 8	2 0	....	150+	6	59,696	1
Pratt (Corona)	3 0	16 0	8 0	....	1500—	73	3,867,369	65
American	0 5	6 9	2 8	....	1500+	4	48,467	1
New Castle (Palos)	0 6	8 9	1 6	400—	2000—	23	522,869	9
Horse Creek (Mary Lee, Gamble)	0 6	8 2	3 3	400±	2000	2	23,574	0.5
Blue Creek	0 0	16 0	1 8	400+	2000+	3	682,590	11
Jagger	0 0	13 6	2 0	....	2000+	7	298,832	5
Jefferson	0 6	3 6	2 3	1000—	3000—	1	36,500	0.5
Black Creek	0 3	3 9	2 2	1000±	3000+	15	190,898	3
Warrior (combined Jefferson and Black Creek)	......	......	2 8	....	....	7	115,951	2
Total	......	......	......	....	....	......	5,995,174	100

An attempt has been made on the accompanying map (Pl XIV) to represent, for the Warrior basin, the areas in which the aggregate thickness of workable coal is between certain arbitrarily selected limits.[a] The next to the lightest tint indicates the area of the Warrior basin within which the aggregate thickness of coal beds 2 feet or over is 10 feet or less. The next darker shade indicates the area within which the aggregate thickness of workable beds is between 10 and 20 feet; the third shade between 20 and 30 feet, and the darkest shade an aggregate thickness of over 30 feet. The exact facts can not be shown on a map of this scale, but only the general relations. It will be observed that the area containing the greatest thickness of coal forms a narrow strip along the eastern margin of the field. In portions of this area the workable coal has an aggregate thickness of more than 50 feet. Only the Pratt bed has been extensively mined in this area, and

[a] This map is based entirely upon McCalley's admirable report on the Warrior coal basin: Geol. Survey of Alabama, 1900.


BIRMINGHAM DISTRICT
FROM
ALABAMA GEOLOGICAL SURVEY REPORTS
Scale
5 0 5 10 15 MILES
LEGEND
Coal Measures
THICKNESS OF COAL IN THE WARRIOR BASIN
Workable coal 10' or less
Workable coal over 20' and less than 30'
Workable coal over 10' and less than 20'
Workable coal over 30'
Coal mines
MARSHALL
CULLMAN
WINSTON
BLOUNT
ETOWAH
WALKER
JEFFERSON
SAINT CLAIR
TALLADEGA
TUSCALOOSA
SHELBY
WARRIOR BASIN
BLOUNT MT. BASIN
CAHABA BASIN
COOSA BASIN
Guntersville
Red Hill
Albertville
Brooksville
Blountsville
Walnut Grove
Attalla
Bangor
Oneonto
Blount Springs
Whitney
Ashville
Springville
Fairview
Ragland
Delmar
Double Springs
Lynn
Nauvoo
Galloway
Winfield
Carbon Hill
Clark
Gamble
Jasper
Warrior
Coaldale
Morris
Village Springs
Coal Valley
Patton
Days Gap
Corona
Cordova
Horse Creek
Fayette
Quinton
Cardiff
Newcastle
Coalburg
Trussville
Broken Arrow
Coal City
Riverside
Pell City
Brompton
Henryellen
Leeds
Gate City
Pratt Mines
Ensley
Dolomite
Oxmoor
Sterrett
Coosa Riv.
Talladega
Renfroe Miles
Bessemer
Adger
Belle Sumter
Connellsville
Brocks Gap
Helena
Pelham
Milldale
Brookwood
Tuscaloosa
Woodstock
Siluria
Lacey
Columbiana
Gurnee
Blocton
Aldrich
Montevallo
Calera
Brierfield
Black Warrior Riv.
87°
86°
34°
JULIUS BIEN & CO. LITH. N.Y.

the other scarcely less valuable beds, together with the large areas of the Pratt yet untouched, contain a reserve fuel supply which will meet all conceivable demands for many generations to come.

METHODS OF MINING.

A general uniformity in mining methods prevails throughout the Birmingham district, with the exception of slight modifications which are rendered necessary chiefly by differences in the structure of the several parts of the district. In the Coosa and Cahaba basins, where the coal-bearing strata generally have dips of 5° to 30°, practically all mines are opened by slopes, the main entry following the dip of the coal. Side entries are turned off on either side at such angles as to secure easy drainage and haulage. From these side entries rooms are laid off on the upper side only, and where the dip is sufficiently steep the coal is loaded into the cars by chutes. Along the upturned eastern margin of the Warrior field the same method is generally employed. With increasing depth the grade of the slope gradually decreases, and on the Pratt bed at a distance of 1,200 to 2,000 feet practically horizontal beds are reached. Both tail-rope and endless-rope haulage is employed. The latter method, owing to its numerous advantages, is gradually replacing the former. By this improved method a double track is required in the slope, one track for loaded cars and one for the returning empties. The cable moves at a comparatively slow rate, about 150 feet per minute, and the cars are from 150 to 200 feet apart. They engage the cable by means of a simple, automatic overhead grip, and a steady continuous supply of coal is delivered at the tipple regardless of the length of the haul.

In the central and western portions of the Warrior field where the coal is mostly above drainage level the mines are opened almost exclusively by drifts. A few shafts are employed for reaching the lower coals. Shafts are also used in the southern part of the basin where the coal-bearing formations pass below drainage level.

Practically all mining is done by the room-and-pillar system, only a single mine reporting the use of the long-wall system. Comparatively little coal is mined by machines—only about 3½ per cent of the output in 1899. This is probably due to the abundant supply of cheap colored labor and the large demand for slack for coking, so that the increased proportion of lump in machine-mined coal is not an important item.

CHARACTER OF THE COAL.

The coal of the Southern Appalachian field does not possess a very wide range in character. It is all bituminous, and a large proportion of it is coking coal. During the early development of the field doubt was often expressed regarding its suitability for the production of good coke, but this doubt was soon dissipated by the practical manufacture on a large scale of a product little, if any, inferior to the Connellsville standard. The installation of washing plants by several of the largest producers in the Birmingham district has greatly improved the average quality of the coke and made it possible to utilize for this purpose a large amount of slack coal which was formerly lost.

The Sewanee coal of the Chattanooga district and the coals occurring at the corresponding horizon in the southwestern portion of the Jellico district are generally well adapted for coking. The yield of coal in coke varies from 48 to 60 per cent. A little more than half the output of the Tennessee Coal, Iron and Railroad Company, at Tracy City and Whitwell, is converted into coke and used in the furnaces at Cowen and South Pittsburg.

Considerable coke is also made at various points along the eastern margin of the field, notably at the State mines at Petros, in the Wartburg basin, and at Rockwood, Dayton, and Soddy, on the eastern edge of the Walden basin. A large part of the coal mined in the Lookout basin in Georgia is also coked.

In the Birmingham district a large amount of coal is coked, the greater part coming from the Pratt bed, although considerable amounts also come from the Blue Creek, Brookwood, and New Castle beds. In fact, practically all the beds in the Warrior basin, as well as those in the northern portion of the Cahaba and Coosa basins, yield coking coal.

In most cases where coke plants are connected with the mines the coal is screened over 1¼-inch bars, and the lump coal is sold for domestic and steam fuel, the screenings being coked direct or after washing.

Most of the mines in the Jellico district yield coal which cokes only indifferently, but forms a higher grade of domestic and steam fuel than the coking coal, and generally commands a higher price. This district produces a small amount of high-grade cannel coal, which is said to equal any found elsewhere in the United States. Its quality is indicated by the fact that 5,000 tons were sold in Europe in 1900.

The coal occurring below the heavy conglomerate beds in the lower part of the Coal Measures differs somewhat widely from the higher coals. It is generally much harder and cleaner, bearing transportation well, and making a high-grade steam and domestic fuel. About 40 per cent of the output of the Bon Air mines, which are upon these subconglomerate beds, is consumed as domestic fuel, while the remaining 60 per cent is about equally divided between railroads and manufacturing establishments.

The southern portion of the Cahaba basin also supplies a high-grade domestic coal, which sells from 40 to 60 per cent higher than the other coals of the district.

The fuel value of a coal is indicated in a general way by its chemical composition, although its adaptability for a particular purpose may be determined by other characteristics which are not shown in the results of a chemical analysis. It is considered advisable, however, to insert a few analyses selected from the best available for this field. The results of the various analyses are not strictly comparable, since the samples were not selected in a uniform manner. The most satisfactory method of estimating the relative fuel values of coals from analyses is by a comparison of their fuel ratios. The fuel ratio is obtained by dividing the percentage of the total fuel constituents, which consists of fixed carbon, by the percentage of volatile combustible matter. This ratio is largest in anthracite and smallest in lignite. In most bituminous coals it is between 1.50 and 3.

Analyses of coals from the Southern Appalachian field.

MADE BY THE NAVY DEPARTMENT, 1893–1898.

No.	Trade name.	Location of mine.	Moisture and non-combustible volatile matter.	Fixed carbon.	Volatile combustible matter.	Ash.	Sulphur.	Fuel ratio $= \frac{F. C.}{V. C. M.}$
1	Black Creek	Warrior, Jefferson County, Ala	4.83	72.76	18.95	3.28	0.17	3.83
2	Sloss	Coalburg, Jefferson County, Ala	2.33	70.31	24.20	2.74	.42	2.90
3	Cahaba	Blocton, Bibb County, Ala	4.16	67.43	24.94	3.27	.19	2.70
4	Pratt	Birmingham, Jefferson County, Ala	2.10	68.35	25.77	3.70	.07	2.65
5	Milldale	Milldale, Tuscaloosa County, Ala	1.28	69.23	27.43	1.77	.28	2.52
6	Newcastle	Gamble, Walker County, Ala	2.78	61.96	24.67	10.59	.43	2.51
7	Cahaba	Blocton, Bibb County, Ala	3.22	64.32	25.70	6.69	.05	2.50
8	Coal Creek	Briceville, Anderson County, Tenn	3.16	65.42	27.22	4.00	.20	2.40
9	Mingo	Hartranft, Claiborne County, Tenn	3.54	62.09	27.97	4.66	1.74	2.21
10	Paint Rock	Oneida, Scott County, Tenn	5.05	61.44	28.11	5.40	.18	2.18
11	Cripple Creek	Briceville, Anderson County, Tenn	3.20	63.42	30.04	3.34	.42	2.11
12	Fraterville	Coal Creek, Anderson County, Tenn	2.37	62.72	31.47	3.44	.30	1.99
13	Jellico	Jellico, Campbell County, Tenn	4.40	61.87	31.56	1.86	.31	1.96
14	Black Diamond	Coal Creek, Anderson County, Tenn	3.34	62.68	31.95	2.03	.25	1.96
15	Corona	Corona, Walker County, Ala	3.04	59.17	30.93	6.09	.77	1.91
16	Montevallo	Aldrich, Shelby County, Ala	1.99	48.99	34.85	14.27	.67	1.40

Analyses of coals from the Southern Appalachian field—Continued

FURNISHED BY OPERATORS.

No.	Name of coal.	Location of mine.	Percentage yield of coal in coke.	Moisture.	Fixed carbon.	Volatile combustible matter.	Ash.	Sulphur.	Fuel ratio= F. C./V. C. M.	Analyst or authority.
1	Milldale	Milldale, Tuscaloosa County, Ala	....	1.40	67.40	24.00	7.20	1.23	2.80	L. A. O. Gaboney.
2	Brookwood	Brookwood, Tuscaloosa County, Ala	74	1.75	65.55	24.15	8.55	1.40	2.71	Do.
3	Carter	Searles, Tuscaloosa County, Ala	....	1.20	66.05	24.90	7.85	.69	2.65	Do.
4	Sewanee	Whitwell, Marion County, Tenn	58	....	70.76	29.24	7.81	.75	2.41	T. C. I. & R. R. Company.
5	Bon Air	Bon Air, White County, Tenn	None.	1.86	64.54	28.67	4.93	.85	2.25	J. C. Wharton, Nashville, Tenn.
6	Coal Creek	Briceville, Anderson County, Tenn	60	.57	63.04	30.41	3.62	.23	2.07	United States Navy Department.
7	Pratt	Muncy, Jefferson County, Ala	56	1.07	64.30	32.08	2.08	.47	2.00	
8	Jellico	Newcomb, Campbell County, Tenn	None.	1.00	64.00	33.00	2.00	....	1.93	Slocum, Knoxville, Tenn.
9	Brushy Mountain	Petros, Morgan County, Tenn	58	....	62.31	32.32	5.37	.81	1.92	E. Tenn. Land Company, 1894.
10	Black Creek	Cullman, Cullman County, Ala	66	.45	63.45	33.80	1.25	.85	1.87	Brainerd.
11	Jefferson	Natural Bridge, Winston County, Ala.	None.	2.98	59.92	34.58	1.90	.61	1.73	
12	Sewanee (washed)	Rockwood, Roane County, Tenn	53	....	58.19	33.81	8.00	.35	1.72	Roane Iron Company.
13	Glenmary	Pineknot, Whitley County, Ky	None.	.93	60.34	35.21	3.12	.38	1.71	Bryant Brothers.
14	Black Creek	Walker County, Ala	52	1.85	60.90	35.60	1.65	.64	1.71	Empire Coal and Coke Company.
15	New Pioneer	Pioneer, Campbell County, Tenn	Some.	....	58.00	37.61	3.42	.97	1.54	Slocum, Knoxville, Tenn.
16	Brushy Mountain	Petros, Morgan County, Tenn	55	1.54	55.74	36.65	3.53	2.54	1.52	Pratt Laboratory, Atlanta.
17	Corona	Corona, Walker County, Ala	None.	2.40	52.99	37.09	7.25	....	1.42	Dr. E. A. Smith.
18	.....do	Walker County, Ala	None.	1.35	51.93	40.59	5.00	1.13	1.27	D. C. Boyce, 1893.
19	Poplar Creek	Oliver Springs, Morgan County, Tenn.	Some.	2.50	50.71	44.81	2.15	2.08	1.13	J. S. Carey, 1893.

Analyses of coals from the Southern Appalachian field—Continued.

REPORTS OF THE ALABAMA GEOLOGICAL SURVEY.

No.	Name of coal.	Location of mine.	Coke.	Moisture.	Fixed carbon.	Volatile combustible matter.	Ash.	Sulphur.	Fuel ratio= F. C./V. C. M.	Analyst.
1	Black Creek	Warrior basin		0.12	71.64	26.11	2.93	0.10	2.74	Dr. William Gesner.
2	Jagger	do		2.66	53.58	24.54	14.65	.47	2.18	Alabama Geological Survey (2 analyses).
3	Newcastle	do		.50	59.69	28.24	10.92	.64	2.11	Dr. Otto Wuth.
4	Haynes	Blount Mountain basin	66	1.46	64.97	31.11	1.46	3.87	2.08	J. M. Pickel.
5	Warrior	Warrior basin			65.12	32.24	1.27	.56	2.01	Lupton.
6	Baine	Blount Mountain basin	66	1.18	64.18	32.35	2.29	.92	1.98	J. M. Pickel.
7	Pratt	Warrior basin		1.02	63.37	32.17	3.34	1.04	1.96	Lupton and Campbell (5 analyses)
8	Peacock	Blount Mountain basin	66	1.49	61.46	32.38	4.67	1.79	1.89	J. M. Pickel.
9	Ragland	Coosa basin	67	.56	60.33	31.77	5.64	1.70	1.89	Do.
10	Yellowleaf	do		1.43	60.85	32.21	4.41	1.10	1.88	Do.
11	Ragland	do	67	.64	59.69	32.13	5.81	1.73	1.85	Do.
12	Cunningham	do	71	.52	52.41	28.24	14.25	4.58	1.85	Do.
13	Corona	Warrior basin		1.52	57.24	31.89	9.34	.00	1.79	Alabama Geological Survey.
14	Woodward	Blount Mountain basin	63	1.17	59.52	34.90	4.41	2.20	1.70	J. M. Pickel.
15	Coal City	Coosa basin	63	1.38	58.80	35.06	5.26	.53	1.67	Do.
16	Haynes	Blount Mountain basin	62	1.27	56.19	36.49	6.05	3.87	1.54	Do.

DEVELOPMENT.

HISTORY OF DEVELOPMENT.

Coal mining is so directly dependent upon cheap transportation that its development on a large scale invariably awaits the development of transportation facilities. Coal was discovered in the Southern Appalachian field by the early settlers, who opened mines in primitive fashion for the supply of local blacksmiths. No mining of any importance, however, was done in Tennessee previous to 1854. In that year the Nashville and Chattanooga Railroad was completed, affording an outlet in connection with the Western and Atlantic Railroad to Atlanta and other points in Georgia and the Carolinas. Mines were in operation at Poplar Creek in 1852, the product being loaded upon barges on Clinch River and thus transported to Knoxville and Chattanooga. Some coal was mined at Rockwood as early as 1840, and hauled to barges on the Tennessee River.

The mines at Aetna were opened in 1854, and the product of the entire State for that year was about 3,000 tons. The next year it increased to over 7,000 tons. With the completion of the Knoxville and Ohio Railroad an outlet to the east was afforded for the product of mines in the Jellico district, and with the completion of the Cincinnati Southern in 1874 mines were opened in the western part of the Jellico district and along the eastern margin of the Chattanooga district, the product going both north and south.

Among the earliest industrial enterprises inaugurated in the South after the close of the war was the Roane Iron Company, which erected furnaces at Rockwood, Tenn., in 1867. Until the completion of the Cincinnati Southern Railroad the product of this furnace, as well as of the coal mines in the vicinity, was shipped by way of the Tennessee River.

In the Birmingham district some coal was mined as early as 1836, chiefly in the northern portion of the Coosa basin, where it was loaded on barges and carried down the Coosa River. A small amount was also mined in Tuscaloosa County and sent to southern Alabama by way of the Warrior River. Mines were opened in the Cahaba field in 1856, in the vicinity of Montevallo. There was considerable activity in mining in the Coosa and Cahaba basins to supply the needs of the Confederate government during the civil war. Mines were operated at Ragland and Montevallo and also in the northern and western portions of the Montevallo basin. After the close of the war there was little demand for Alabama coal until 1870, when the old Oxmoor furnace was rebuilt, and the adaptability of the coal in this field for coking was demonstrated. The exceptional facilities for the manufacture of iron in the Birmingham district were soon recognized, and with the erection of numerous furnaces the demand for fuel rapidly increased.

Development of the Southern Appalachian coal field by decennial periods.

State.	1880.			1890.			Increase of 1890 over 1880.			
	Production.	Value.	Average price per ton.	Production.	Value.	Average price per ton.	Production.	Per cent.	Value.	Per cent.
	Tons.			*Tons.*			*Tons.*			
Tennessee	495,131	$629,724	$1.27	2,169,585	$2,395,746	$1.10	1,674,454	34	$1,766,022	28
Georgia	154,644	231,605	1.49	228,337	238,315	1.04	73,693	47	6,710	3
Alabama	323,972	476,911	1.47	4,090,409	4,202,469	1.03	3,766,437	116	3,725,558	78

State.	1900.			Increase of 1900 over 1890.			
	Production.	Value.	Average price per ton.	Production.	Per cent.	Value.	Per cent.
	Tons.			*Tons.*			
Tennessee	3,708,562	$4,223,082	$1.14	1,538,977	70	$1,828,336	80
Georgia	315,557	370,022	1.17	87,220	38	131,707	55
Alabama	8,394,275	9,793,785	1.17	4,303,866	105	5,591,316	133

PRODUCTION.

The production of coal in the Southern Appalachian field has shown a fairly steady increase since systematic mining operations were resumed after the close of the war. The production of the several States included in the field for the decennial periods since 1880 is shown in the table above. The production of the three counties of Kentucky which properly belong with this field is not included. The curves on the accompanying diagram (fig. 26) show the production of the several States, together with the total production of the field and the total value of the product for each year between 1880 and 1900. It will be noted that the field has shown a steady increase in total production with the exception of three years, when there was a decrease, namely, in 1886, 1893, and 1894. The line representing total value of product follows closely the line of total production. Between 1886 and 1893 the average price per ton was slightly more than $1; between 1894 and 1898 the average price was less than $1, and between 1899 and 1900 it again passed above $1. The greatest fluctuations in production have been in Alabama, which also shows the most rapid increase. In 1880 the production of Alabama was only little more than half that of Tennessee, while in 1900 it was more than twice the Tennessee production. The Georgia production has been remarkably uniform during the period represented on the diagram. It has remained throughout this period under half a million tons, and, owing to the small area of available coal in this State, will probably never much exceed that amount.

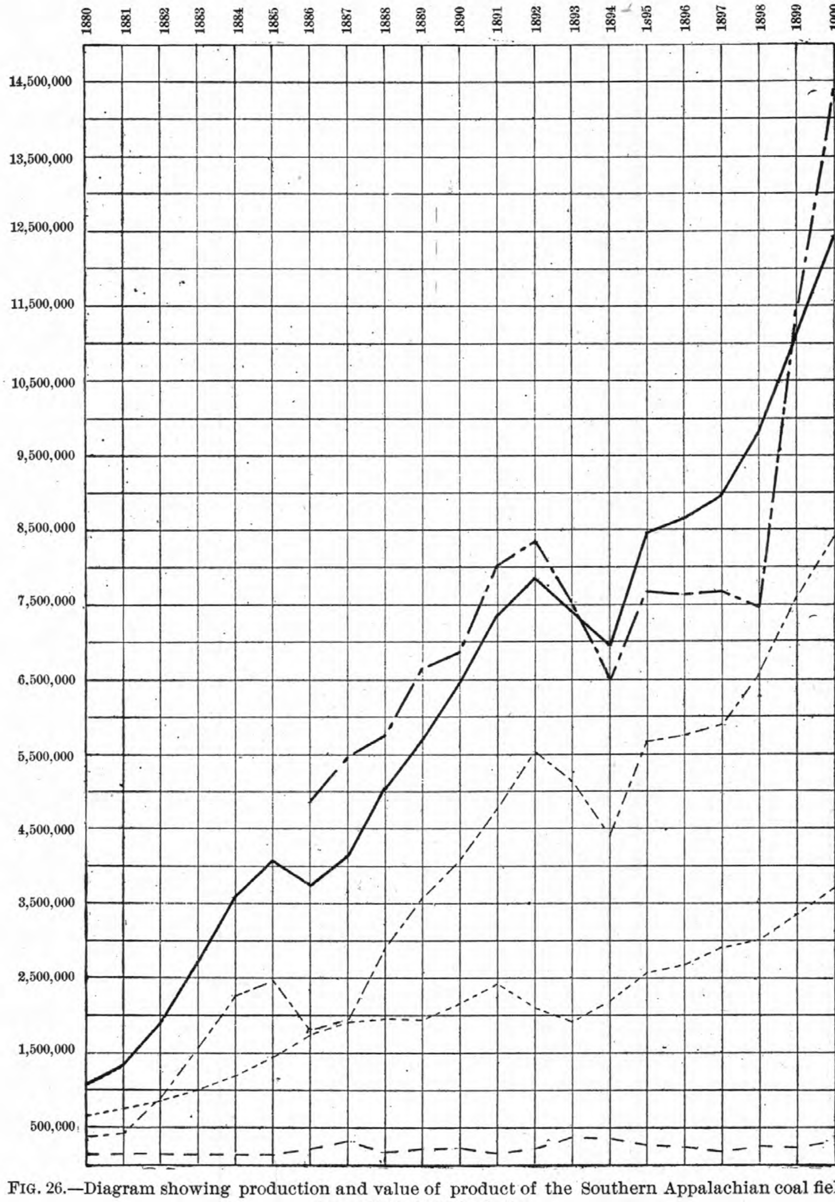


FIG. 26.—Diagram showing production and value of product of the Southern Appalachian coal field from 1880 to 1900, inclusive.

------ Tennessee. — — — — — Georgia. —·—·—·— Alabama. ——— Total production. ▬ ‒ ▬ Total value.

Scale {500,000 tons to the square; $500,000 to the square.

Production and distribution of product of the Southern Appalachian coal field for 1900.

Subdivisions of Southern Appalachian field.	Production.	Value at mines.	Average value per ton.	Railroad fuel.		Manufacturing fuel.		Domestic fuel.		Made into coke.	
				Quantity.	Per cent.	Quantity.	Per cent.	Quantity.	Per cent.	Quantity.	Per cent.
	Sh. tons.			*Sh. tons.*		*Sh. tons.*		*Sh. tons.*		*Sh. tons.*	
Tennessee	3,708,562	$4,223,082	$1.14	995,188	27	1,258,620	34	673,216	18	781,538	21
Georgia	315,557	370,022	1.17	18,000	6	151,089	48	....	.....	146,468	46
Alabama	8,394,275	9,793,785	1.17	2,319,867	28	3,028,716	36	1,095,493	13	1,950,199	23
Total	12,418,394	14,386,889	1.16	3,333,055	27	4,438,425	36	1,768,709	14	2,878,205	23

COST OF MINING.

In the Jellico district the cost of mining varies between 40 and 65 cents for run-of-mine coal, the average for 24 mines being 49 cents. For coal screened over 1¼-inch bars the rate is from 69 to 85 cents, averaging 77 cents. The miners in this district are fairly well organized, and in past years strikes have been somewhat frequent. No labor difficulties, however, have occurred during the last year. A fruitful source of irritation in this district in the past has been the presence of convicts in some of the mines. This has been removed by the opening of State mines at Brushy Mountain, where convicts are employed in such a manner that they do not come into direct competition with free labor. With the above cost for mining, the total cost of the coal on board cars at the mines varies from 85 cents to $1.25. As shown on one of the accompanying tables, the average value of the coal at the mines for 1900 was slightly over $1 a ton.

In the Birmingham district the miners are paid at most of the mines, particularly those which supply the furnaces, on a sliding scale, depending on the selling price of iron. The miners are well organized, but strikes have hitherto been very infrequent. Both white and colored labor is employed in these mines, apparently entirely without friction. The coal in the Montevallo district costs considerably more for mining on account of the steep inclination of the beds, but this additional cost of production is compensated by the better price which the product brings as a domestic fuel.

PROSPECTIVE DEVELOPMENT.

Inquiries were addressed to the coal operators as to the immediate prospects for improvement in their business. The following table indicates the proportion of operators reporting favorable prospects; also the ratio of present output to present capacity of the mines. It will be observed that a large proportion of the operators report favorable prospects, and at many points plans are being made for a very greatly increased output in the near future:

Prospects of development in the Southern Appalachian field.

State.	Number counties producing coal.	Number commercial mines.	Production, 1900.	Estimated capacity of mines, 1900.	Ratio of production to capacity.	Per cent of mines reporting prospective increase of capacity.
			Short tons.	*Short tons.*		
Tennessee	13	59	3,708,562	4,938,449	75	84.6
Georgia	2	2	315,557	347,113	91	......
Alabama	12	114	8,394,275	11,292,761	74	68.0

DISTRIBUTION.

LOCATION AND CHARACTER OF MARKETS.

The markets supplied by the coal from the Southern Appalachian field are chiefly to the southeast, south, and southwest. Throughout the whole of its territory it comes in competition with Pennsylvania anthracite chiefly as domestic fuel. Comparatively little anthracite, however, is used even for domestic fuel except along the Atlantic and Gulf coast, which is reached by cheap water transportation. Considerable coal from the Jellico district goes to the markets of central and western Kentucky, competing with the coals of eastern Kentucky and West Virginia, and also with the coal of the eastern interior field of western Kentucky and Indiana. The superior quality of the Jellico coal, especially for domestic and steaming purposes, enables it to encroach somewhat upon the territory which would normally be supplied by the western Kentucky and Indiana fields. Most of the product from the Jellico district finds an outlet through Knoxville toward the southeast, supplying the greater part of eastern Tennessee, western North and South Carolina, and a portion of northern Georgia. With the completion of the Tennessee Central Railroad the coal from this district will doubtless find a market at Nashville and other points in middle Tennessee.

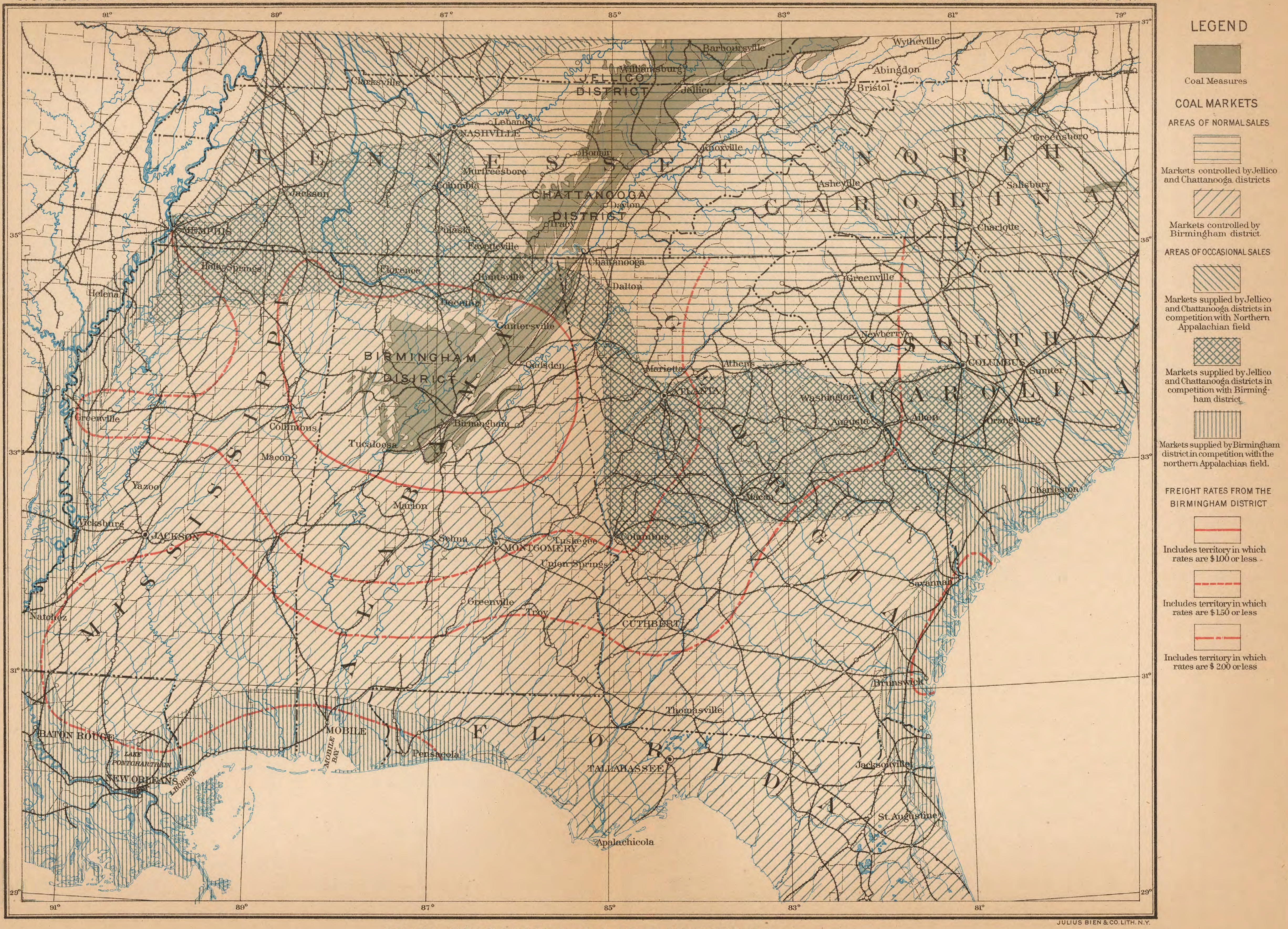
Probably 50 per cent of the coal mined in the Chattanooga district is converted into coke and used at the various furnaces in this district. The Sewanee bed, which is the one furnishing a very large proportion of the product, is particularly well adapted for coking, and at several places, as Rockwood and Dayton, the entire output of the mines is used in furnaces at those points. That portion of the output from this district which is not coked finds a market in central and western Tennessee, a small portion going as far west as the Mississippi River, but a larger proportion going southeast into northern Georgia and South Carolina. In both of these fields it competes with coal from the Birmingham district.

The following table shows the principal markets supplied by coal from the Jellico district and the prevailing freight rates:

Freight rates from the Jellico district to—

Cincinnati, Ohio	\$0.75 to \$0.85	Spartanburg, S. C	\$1.85
Louisville, Ky	.85 to 1.15	Columbia, S. C	2.20
Lexington, Ky	1.15	Port Royal, S. C	\$1.95 to 2.05
Winchester, Ky	1.15	Greenville, S. C	1.85
Richmond, Ky	1.45	Charleston, S. C	1.95
Chattanooga, Tenn	.65 to .85	Atlanta, Ga	1.30 to 1.45
Memphis, Tenn	1.50	Toccoa, Ga	1.95
Knoxville, Tenn	.65	Macon, Ga	1.75
Nashville, Tenn	1.00 to 1.40	Athens, Ga	1.85
Bristol, Tenn	1.60	Augusta, Ga	2.05
Charlotte, N. C	2.10	Rome, Ga	1.10
Salisbury, N. C	2.10	Brunswick, Ga	1.80 to 2.05
Asheville, N. C	1.60	Huntsville, Ala	.75 to 1.00

The Birmingham district practically controls the markets of southern and western Georgia and the whole of Alabama and Mississippi, except the region immediately adjacent to the Mississippi River. Within a belt between Atlanta, Ga., and Columbia, S. C., it competes with the coal from East Tennessee, and also from Virginia and Kentucky. Along the Atlantic coast and in Florida it competes with coal from the Northern Appalachian field, which has the advantage of cheap water transportation, and is also preferred by manufacturers for steam raising to the softer Southern coals. Along the Gulf coast from Pensacola westward, as well as in the territory immediately adjoining the Mississippi River, the product of the Birmingham district competes with the Ohio, Pennsylvania, and West Virginia coal, which is brought down the river in barges. The Birmingham district has recently become a strong competitor for this Mississippi River and New Orleans trade. The Southern Railroad has erected docks at Greenville, Miss., and established a line of barges between that point and the Lower Mississippi markets. The principal demand for fuel in this region is for the sugar mills. Freight rates are such that the coal can be supplied by rail to the markets which are not immediately upon the river cheaper than by barge, since no extra handling is required. There is also a considerable demand for bunker coal by steamers sailing from Pensacola, Mobile, and New Orleans, and a small amount of coal is exported from Mobile, chiefly to Mexican and Central American ports.



MAP SHOWING COAL MARKETS

Scale

100 75 50 25 0 100 MILES

TRANSPORTATION.

The Southern Appalachian coal field is fairly well supplied with transportation facilities. Four lines reach the Jellico district. The Louisville and Nashville and the Cincinnati Southern supply the markets to the north and northwest. The Tennessee Central supplies Nashville and points in middle Tennessee, while the Southern and the Cincinnati Southern, through Knoxville and Chattanooga, supply the markets reached by roads running toward the southeast and east. Transportation is furnished in the Chattanooga district by the Nashville, Chattanooga and St. Louis, and the Cincinnati Southern, with their connections at Chattanooga. The Birmingham district is reached by several important systems. The markets in the eastern part of its territory are supplied chiefly by the Southern Road and the Central of Georgia, in the south and southwest by the Louisville and Nashville and Alabama Great Southern, and in the west and northwest by the Louisville and Nashville, Kansas City, Memphis and Birmingham, and the Southern.

The accompanying sketch map (Pl. XV) shows the transportation facilities and freight rates from the Birmingham district. The latter are shown by a series of contour lines. All points within the first line have freight rates on coal from the Birmingham district less than $1 a ton. The rate to points between the first and second lines is between $1 and $1.50; between the second and third, between $1.50 and $2; and outside of the third line it is over $2. Certain irregularities in these lines will be noted. For example, the rates to Memphis and Greenville are less than to points much nearer in Tennessee and Mississippi. Also the rail rates to Vicksburg, Baton Rouge, and New Orleans are less than $2, while the rates are $2 or over to points in southern Mississippi and eastern Louisiana. These lower rates to Mississippi River points are due to competition with river transportation. The same is true of Mobile and Pensacola. Rates to Savannah and Brunswick, Ga., are also under $2, due to competition with water transportation from the Northern Appalachian field. Aside from those points where competition is active between rail and water transportation, the rates are practically proportional to distance.

THE EASTERN INTERIOR COAL FIELD

BY

GEORGE H. ASHLEY

CONTENTS.

ILLUSTRATIONS.

THE EASTERN INTERIOR COAL FIELD.

By George H. Ashley.

GEOGRAPHIC RELATIONS.

LOCATION AND BOUNDARIES.

The Eastern Interior coal field covers most of Illinois, the southwest corner of Indiana, and a small portion of western Kentucky. The accompanying map (Pl. XVI) shows the boundaries of the field and also the inspection districts of the portion which lies in Illinois. The field is regular in outline, with few isolated outliers. A considerable area is cut off on the western border by the Illinois River and Crooked Creek, and a few small outliers occur in Illinois, in the northern part of Monroe County, and in Missouri, west of St. Louis and St. Charles. There are also a number of small outlying areas of Coal Measure rocks in Illinois north of the main fields.

It is probable that the beds forming the Eastern Interior coal field had originally a much greater extent than at present. They may have extended eastward across Kentucky and westward across the Mississippi Valley, forming a continuous sheet from the present Appalachian field to the Western Interior field. If these three fields were originally continuous they have since been isolated by the erosion of the rocks formerly occupying the intervening areas.

The Eastern Interior coal field is estimated to have an area of 35,000 square miles in Illinois, 6,500 square miles in Indiana, and 4,500 square miles in Kentucky, making a total for the entire field of 46,000 square miles. The field occupies 80 counties in Illinois, 26 counties in Indiana, and 20 counties in Kentucky. Of these, coal is mined in 58 in Illinois, 21 in Indiana, and 11 in Kentucky.

Although the boundaries of this field have not been traced out in great detail, it is scarcely probable that future examinations will extend its area by an appreciable amount.

SUBDIVISIONS OF THE FIELD.

For convenience of description the field is subdivided into three unequal portions, on State lines. The only natural subdivisions are those based on differences in stratigraphy; but since the stratigraphy has not been worked out with the same detail in all portions of the field, it is not at present possible to make subdivisions on this basis. Though stratigraphic lines can not be sharply drawn, it is desirable, even in an economic discussion, to recognize these divisions as far as possible. On the accompanying map, therefore, the following divisions are shown by distinct colors: First, the area in which all the outcropping rocks belong to the upper part of the measures and contain no workable coal, and, second, the area in which the strata containing the workable coals outcrop. A third division, consisting of the area in which the basal portion of the measures contains little or no workable coal, might be discriminated in Indiana, but not in Illinois and Kentucky.

In Indiana the middle division can be subdivided into the lower or so-called "block coal" field, and the upper or "bituminous" field. These divisions are shown on the map as far as our present knowledge will warrant.

GEOLOGIC RELATIONS.

AGE OF THE COAL-BEARING ROCKS.

The coal-bearing rocks of this field belong to the Coal Measures division of the Carboniferous. The basal sandstones are determined by paleontologic data to be of the same age[a] as the Pottsville conglomerate of Pennsylvania, while the highest workable coals are believed to be stratigraphically equivalent to the Freeport group or Conemaugh series of the Allegheny field, which is a little below the horizon of the Pittsburg coal.[b] There is some evidence that the upper part of the Carboniferous of this field is of Permian age, though not sufficient work has yet been done to satisfactorily demonstrate that conclusion.

STRATIGRAPHY OF THE COAL-BEARING ROCKS.

The detailed work of the Indiana coal survey from 1896 to 1898 demonstrated that, so far as that State is concerned, no general section can be given, the correlation of coal beds any distance apart being generally hypothetical. This work also showed that previous correlations with the coal beds of other States could not be relied upon, and that until detailed surveys of Illinois and Kentucky have been made no reliance can be placed on correlations between the different parts of the field in the several States.

The Coal Measures rest unconformably on the underlying formations. At the southern margin of the field they lie on the Chester or Kaskaskia limestone, which, in southern Illinois, has a thickness of 800 feet. Northward, along both the eastern and western borders of the coal field, the Chester thins out, having been eroded before the

[a] Dept. Geol. and Nat. Res. Indiana, Twentieth Ann. Rept., p. 354.
[b] Geologic Atlas U. S., folio 67, Danville, Illinois-Indiana.

Counties IN ILLINOIS

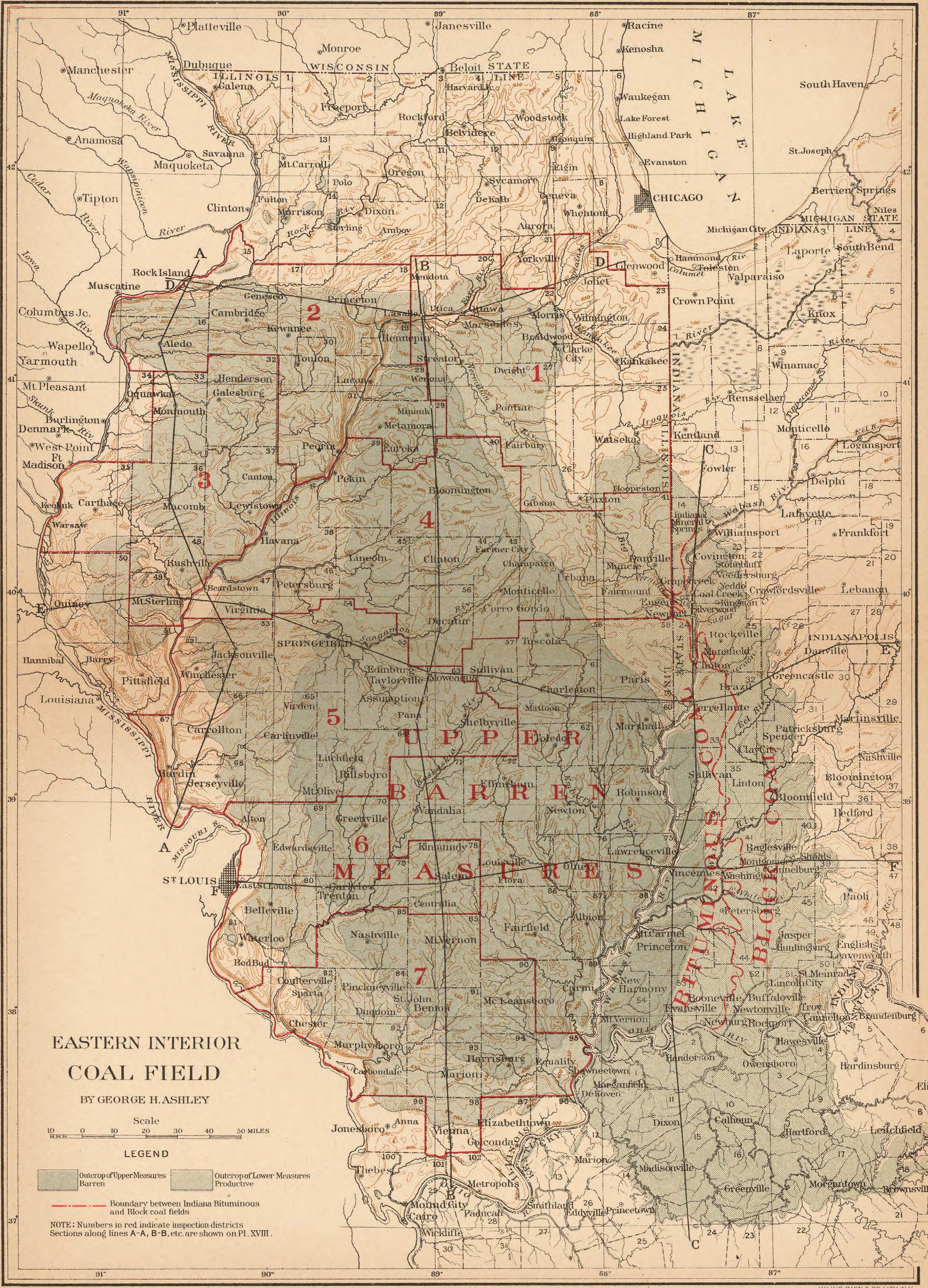
1 JO DAVIESS
2 STEPHENSON
3 WINNEBAGO
4 BOONE
5 MC HENRY
6 LAKE
7 COOK
8 DUPAGE
9 KANE
10 DEKALB
11 OGLE
12 LEE
13 CARROLL
14 WHITESIDE
15 ROCK ISLAND
16 MERCER
17 HENRY
18 BUREAU
19 PUTNAM
20 LASALLE
21 KENDALL
22 GRUNDY
23 WILL
24 KANKAKEE
25 IROQUOIS
26 FORD
27 LIVINGSTON
28 MARSHALL
29 WOODFORD
30 STARK
31 PEORIA
32 KNOX
33 WARREN
34 HENDERSON
35 HANCOCK
36 McDONOUGH
37 FULTON
38 MASON
39 TAZEWELL
40 McLEAN
41 VERMILION
42 CHAMPAIGN
43 PIATT
44 DEWITT
45 LOGAN
46 MENARD
47 CASS
48 SCHUYLER
49 BROWN
50 ADAMS
51 PIKE
52 SCOTT
53 MORGAN
54 SANGAMON
55 CHRISTIAN
56 MACON
57 MOULTRIE
58 DOUGLAS
59 EDGAR
60 CLARK
61 COLES
62 CUMBERLAND
63 SHELBY
64 MONTGOMERY
65 MACOUPIN
66 GREENE
67 CALHOUN
68 JERSEY
69 MADISON
70 BOND
71 FAYETTE
72 EFFINGHAM
73 JASPER
74 CRAWFORD
75 LAWRENCE
76 RICHLAND
77 CLAY
78 MARION
79 CLINTON
80 ST. CLAIR
81 MONROE
82 RANDOLPH
83 WASHINGTON
84 PERRY
85 JEFFERSON
86 WAYNE
87 EDWARDS
88 WABASH
89 WHITE
90 HAMILTON
91 FRANKLIN
92 JACKSON
93 WILLIAMSON
94 SALINE
95 GALLATINE
96 HARDIN
97 POPE
98 JOHNSON
99 UNION
100 ALEXANDER
101 PULASKI
102 MASSAC

INDIANA

1 LAKE
2 PORTER
3 LAPORTE
4 ST. JOSEPH
5 MARSHALL
6 STARKE
7 NEWTON
8 JASPER
9 PULASKI
10 FULTON
11 CASS
12 WHITE
13 BENTON
14 WARREN
15 TIPPECANOE
16 CARROLL
17 CLINTON
18 HOWARD
19 TIPTON
20 HAMILTON
21 BOONE
22 MONTGOMERY
23 FOUNTAIN
24 VERMILION
25 PARKE
26 PUTNAM
27 HENDRICKS
28 MARION
29 JOHNSON
30 MORGAN
31 OWEN
32 CLAY
33 VIGO
34 SULLIVAN
35 GREENE
36 MONROE
37 BROWN
38 JACKSON
39 LAWRENCE
40 MARTIN
41 DAVIESS
42 KNOX
43 GIBSON
44 PIKE
45 DUBOIS
46 ORANGE
47 WASHINGTON
48 HARRISON
49 CRAWFORD
50 PERRY
51 SPENCER
52 WARRICK
53 VANDERBURG
54 POSEY

KENTUCKY

1 UNION
2 HENDERSON
3 DAVIESS
4 HANCOCK
5 BRECKENRIDGE
6 MEADE
7 HARDIN
8 GRAYSON
9 OHIO
10 McLEAN
11 WEBSTER
12 CRITTENDEN
13 LIVINGSTON
14 CALDWELL
15 HOPKINS
16 MUHLENBERG
17 BUTLER
18 EDMONSON
19 HART
20 BARREN
21 WARREN
22 LOGAN
23 TODD
24 CHRISTIAN
25 TRIGG
26 LYON
27 MARSHALL
28 McCRACKEN
29 BALLARD
30 CARLISLE
31 GRAVES



Coal Measure rocks were deposited, and the latter rest on successively lower members of the Lower Carboniferous, first, upon the St. Louis, and, as the northern end is approached, upon the Keokuk and Knobstone. Finally, at the northern edge of the field, the Devonian and Lower Silurian formations underlie the Coal Measures.

The Coal Measures in this field, including the upper measures, which may prove to be of Permian age, reach a maximum thickness of about 1,200 feet. The following table shows the main divisions of the coal-bearing rocks:

Main divisions of coal-bearing rocks in Eastern Interior coal field.

		Feet.
Permian?	Merom group; upper or barren measures	0 to 400
Coal Measures	Wabash group; main coal-bearing measures	100 to 600
	Mansfield group; basal sandstone member	0 to 200

The lower member, generally known as the Millstone grit, or, in Indiana, as the Mansfield sandstone, has a maximum thickness of 200 feet. It is mainly a coarse-grained, cross-bedded sandstone, with thin beds of coal occurring at or near its base. It appears to be confined to the borders of the field, thinning out toward the center of the basin and also becoming inconspicuous toward the northwestern end.

Between the Mansfield sandstone and the overlying Illinois group, at least in Indiana, there is an unconformity. Hence the lower portion of the middle division, the Wabash group, which is found in the southern part of the field, is lacking toward its northern end, and its absence greatly reduces the thickness of the Coal Measures in that direction.

The stratigraphic details of this central or main division of the Coal Measures, here called the Wabash group, vary greatly. In several cases observed in Indiana the distance between two beds which can be identified varies nearly 100 feet in adjoining counties, or even within the same county. As yet no satisfactory basis has been found on which to subdivide this group, and it will therefore be treated as a unit. In the recently published State report on the coals of Indiana the coal-bearing rocks were subdivided into eight divisions, based on that number of main coals or coal horizons. The coal beds were regarded as forming the lower limits of the several divisions and bore the same numbers. Thus Coal VI marked the base of Division VI, minor coals in that division being designated Coals VIa, VIb, etc. This was a purely artificial system, adopted for convenience in mapping and discussing the coals.

In Illinois the coals have been numbered from 1 to 15, coal 7 being the highest bed which is worked. No attempt to subdivide the Coal Measures in that State has been made.

In Kentucky the coals have been numbered and lettered, the numbers beginning at the bottom and running up to 12. Nos. 9, 11, and 12 are the principal coals worked. The letters begin at the top, coals A, B, and D corresponding to 12, 11, and 9, respectively. The numbers appear to be most generally used at present.

At the northern end of the junction between the Indiana and Illinois fields, coals 6 and 7 of the Illinois section are believed to correspond to coals VII and VIII of the Indiana section. Farther south there seems to be a still closer correspondence in the numbers of the coals.

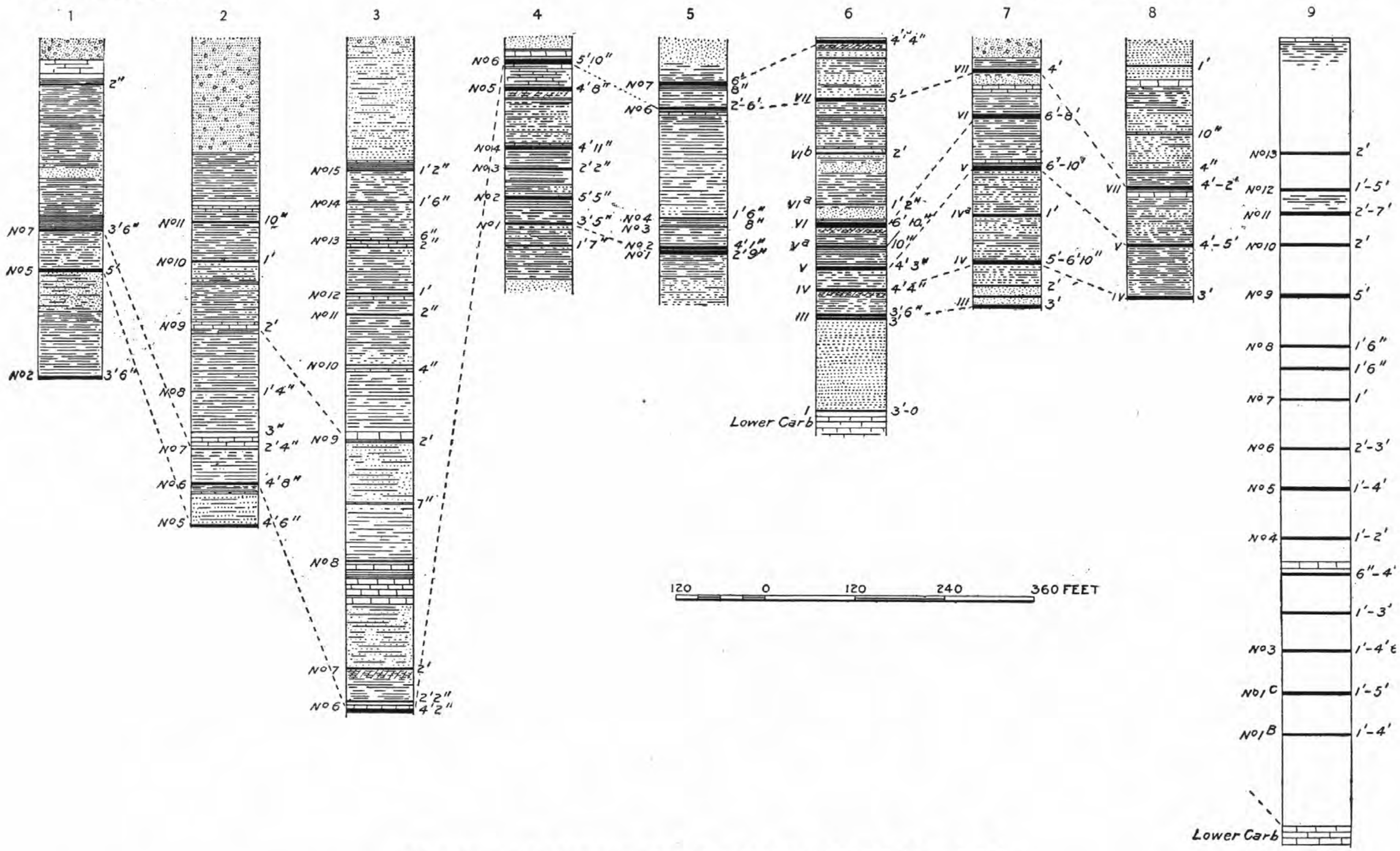
In the southern portion of the field, however, no certain correlations can at present be made. For the purpose of illustrating the stratigraphy of the coal-bearing rocks, sections have been selected from various parts of the field and are shown on Pl. XVII. The probable correlations between the more important coal beds in different portions of the field are indicated, so far as they can be at present. These sections show the predominance of shale, which characterizes the field. Sandstones, although locally thick, are generally inconstant. The limestones, on the other hand, although usually thin and impure, are fairly constant, at least sufficiently so to be of great help in tracing the coals. The coals themselves will be discussed in the next general division.

STRUCTURE OF THE FIELD.

The structure of this field is that of an elongated basin, whose lowest portion is in southeastern Illinois, toward which the strata dip from every direction. The five structure sections forming Pl. XVIII show the main features of the basin. Sections A, B, and C extend approximately north and south, while D, E, and F extend in a general east-west direction on the lines shown on the map. At the center of the basin there is an area of considerable extent within which the strata are nearly horizontal. This lies between the Wabash and Embarras rivers on the east, the Kaskaskia River on the northwest, and the Louisville and Nashville Railway on the south. The northern part of the field is disturbed by a sharp fold or fault, with a downthrow to the west of several hundred feet. This fold extends from the northwest corner of Illinois in a southeast direction, crossing the Illinois River near Lasalle and disappearing near the headwaters of the Embarras River. To the west of this fold the dip of the strata in Illinois is about 7 feet to the mile,[a] and this dip continues from the northwestern edge of the field nearly to the mouth of the Illinois River.[b]

In Indiana the major dip is everywhere toward the center of the basin, being south of west in the northern part of the field, west in the neighborhood of the Baltimore and Ohio Southwestern Railway, and north of west as the Ohio River is approached. The dip in that State averages about 24 feet to the mile, running up to 100 feet to the mile for a few miles in a few places. As a rule, the greatest dip

[a] Geology of Illinois, Vol. III, 1867, p. 16.
[b] Mon. U. S. Geol. Survey, Vol. XXXVIII, p. 554.



STRATIGRAPHIC SECTIONS OF THE EASTERN INTERIOR COAL FIELD.

1, Shaft at Oglesby, Lasalle County, Ill.; 2, air shaft at Decatur, Macon County, Ill.; 3, shaft at Kinmundy, Marion County, Ill.; 4, boring at Galum Creek, Perry County, Ill.; 5, boring at Danville, Vermilion County, Ill.; 6, connected section from southern Vermilion and Parke counties, Ind.; 7, connected section from Dugger and Linton, Sullivan and Parke counties, Ind.; 8, connected section from Henderson, Ky., and Evansville, Ind.; 9, generalized section of Kentucky coal measures (Norwood).

there is not at the edge of the field, but some distance in toward its center.

Passing into Kentucky the dip swings more to the north, but is much influenced by one or more irregularities there. Most notable of these is what has been called the "Rough Creek anticlinal," extending from Leitchfield past Hartford, Calhoun, and Morganfield into Illinois.[a] This uplift appears to be either a sharp monocline or a fault, dividing the Coal Measures of the State into two northward-dipping blocks, separated by a narrow belt in which are high and irregular southward dips. The uplift is sufficient to expose some of the Lower Carboniferous limestones. Just within and at the south border of the field occur two folds or faults parallel to the one mentioned above, from which the strata dip northward. Over much of the field minor faults, folds, and irregularities of many kinds are common.[b]

THE COAL.

INDIANA.

NUMBER AND EXTENT OF WORKABLE BEDS.

In Indiana coal has been found at 20 horizons at least, as many as 17 beds having been struck in a single drilling within a vertical distance of 800 feet. It is probable that the number of beds in Illinois is fully as great as in Indiana. Most of these are thin, but beds sufficiently thick to be workable occur at 8 horizons at least, though, as a rule, not more than 3 beds are workable at any one point, and usually not more than 1, while large areas, amounting to a considerable percentage of the field, are not underlain by workable coal.

For convenience of description the coals of Indiana are subdivided into 4 groups, as follows: (1) coals of the Mansfield group; (2) coals of the lower part of the Wabash group (corresponding to Divisions II, III, IV, and V (in part) of the nomenclature of the Indiana survey); (3) coals of the upper part of the Wabash group (corresponding to Divisions V (in part), VI, VII, and VIII); (4) Merom group.

Coals of the Mansfield group.—The rocks of the Mansfield group outcrop in a belt from 5 to 20 miles wide along the eastern border of the field. They contain near their base sometimes one and in a few cases two coals, which are occasionally found to be workable over very small areas. Generally these coals are thin or lacking.

Coals of the lower part of Wabash group (Divisions II, III, IV, and V (in part) of the Indiana survey).—The rocks of the Wabash group outcrop over a broad belt lying west of the outcrop of the Mansfield, last mentioned. They cover central Fountain and Parke counties, nearly

[a] Geological Survey Kentucky, Vol. V, pt. 5, p. 97; Vol. IV, pt. 7, pp. 302, 311; Vol. III (old series), pp. 112, 147; Rept. Insp. Mines Kentucky, 1895, p. 253.
[b] Rept. Insp. Mines Kentucky, 1895, p. 253.

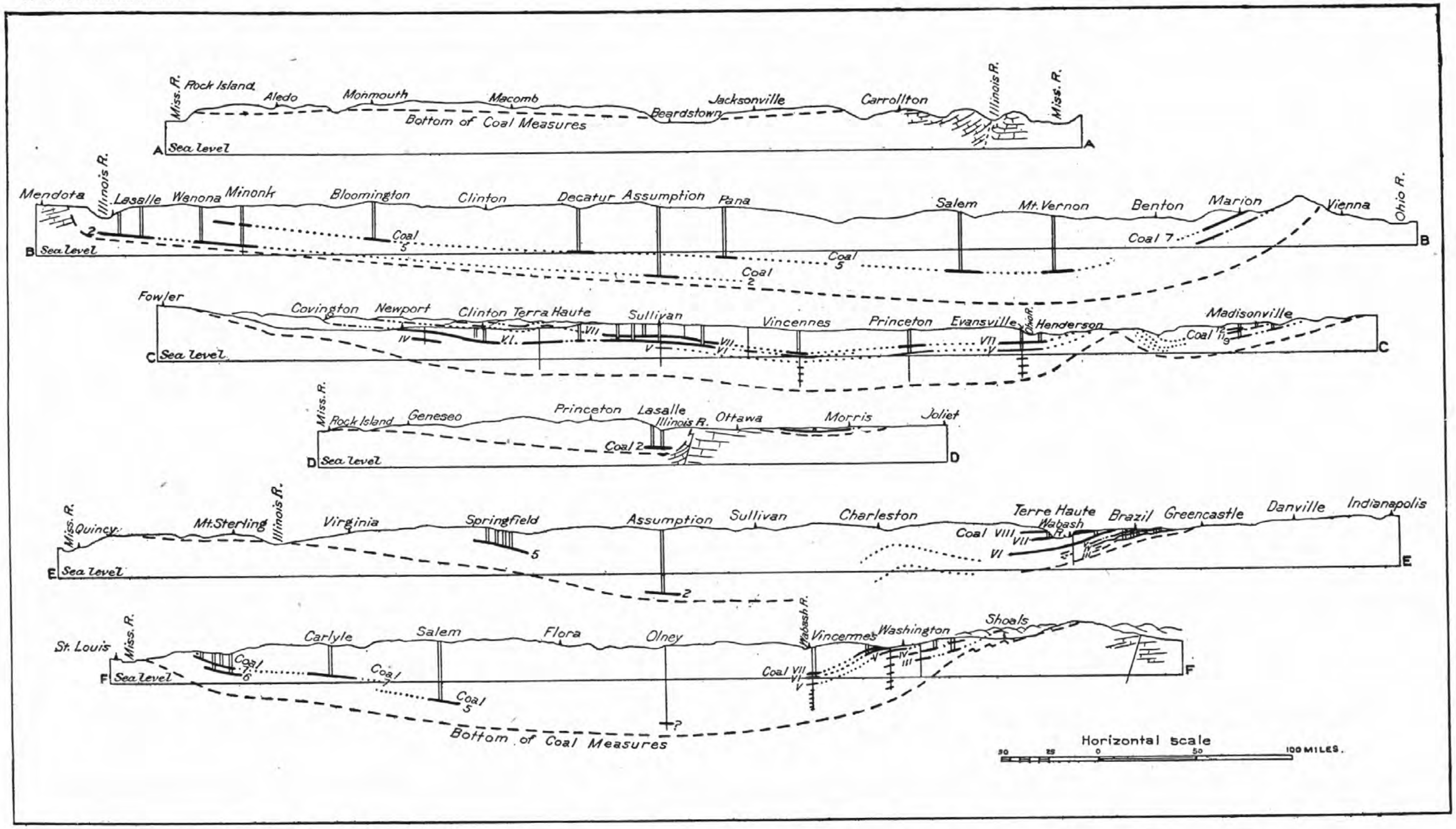
all of Clay County, western Greene County, practically all of Daviess, Dubois, and Spencer counties, the eastern portions of Pike and Warrick counties, and western Perry County. The coals contained are the well-known "Indiana block coal," the cannel coal of Cannelsburg, and semiblock coals. The coals lie in small basins which vary in extent from a few acres to several square miles; this variation is due to the irregular surface upon which they were deposited. The coals attain a thickness of 3 to 5 feet in the center of each basin, but thin out to a few inches between the basins. Notwithstanding this irregularity in thickness, it is often possible to trace one of these coals with much certainty over a considerable area.

Toward the north, coal V, which elsewhere belongs in group 3, is similar in character, and will therefore be considered with the coals of group 2. The most prominent characteristic of the coals of this group is that they are cut by a series of very perfect cleavage planes which intersect each other nearly at right angles and divide the coal up into rectangular blocks. It is from this that the name "block coal" is derived.

Starting at the north, coals II and III are lacking and coals IV and V are workable only locally nearly to the south side of Parke County. The principal workable areas are as follows:

At Fall Creek, west of Indiana Mineral Springs, Warren County, coal V is 3 feet to 4 feet 3 inches thick, and has an extent of several hundred acres; it lies above drainage level. From Stone Bluff to Veedersburg, Fountain County, coal IV forms an extensive deposit, 3 to 4 feet thick, but mostly too thin to work; it occurs above or just below drainage level. At Yeddo, Fountain County, coal V is 5 feet thick and has an extent of several thousand acres; it lies just below drainage level. At Coal Creek post-office (Snoddy's Mill), coal IV is 5 to 7 feet thick, and has an extent of several thousand acres. This is one of the best undeveloped fields in the State; the coal occurs at drainage level. East of Kingman there is a small area of coal V, 3 to 7 feet thick; the coal occurs at drainage level. At Silverwood coal V is 3 to 7 feet thick and has an extent of a few thousand acres; it occurs at drainage level. At Sugar Mill Creek, Parke County, coal IV is 4 to 5 feet thick and has an area of several hundred acres; it is at drainage level. At Mecca coals III and IV have a thickness reaching in places 6 feet 10 inches, and occur at a depth of 100 to 150 feet; there appear to be several square miles of workable coal, reaching over into Vermilion County. At Sand Creek coal V is 5 feet thick with an extent of a few hundred acres. These coals are of workable thickness at a few other places, some of which may later prove extensive fields.

Along the south edge of Parke County the Brazil block coal field sets in and extends south across the eastern half of Clay County to the south county line and along the higher divides well into Owen County.



STRUCTURE SECTIONS OF THE EASTERN INTERIOR COAL FIELD ALONG LINES A-A, B-B, C-C, D-D, E-E, AND F-F OF PLATE XVI.

Coals V, IV, and III, known locally as the "rider, upper, and lower block coals," run through this field. The average thickness of the coal worked here is 3 feet 1 inch, the average of the beds as a whole being much less. The coals run from above drainage level at the east to 100 feet or more below drainage level at the west. Coal V is workable at only a few places. It is characterized by a cover of black shale overlain by limestone. Coal IV is the main coal here. It averages a little over 3 feet, running up to 5 feet in the center of some of the basins. It has a poor roof of shale or sandstone. It is characterized by a 2-inch "bench mining" a little below the center. Coal III is found 20 to 30 feet lower, and is a little thinner and more pockety than coal IV. It is characterized by a smooth parting 6 inches from the top, and by being underlain by a bed half bone and half good coal that runs from 0 to 3 feet thick. The roof is usually shale. Most of this field northeast of Brazil and immediately south has been worked out. Much coal still exists west and northwest of Brazil and between Clay City and Patricksburg.

In crossing Greene County there is a fine field of coal IV from 5 to 6½ feet thick at Linton. This covers several square miles around and northwest of Linton. It runs from drainage level on the east to 100 feet or more in depth on the west. It splits toward the southwest. The roof is shale, serving well in pick mines; the floor is sandstone. The south end of this field is nearly exhausted, but a large body of coal extends to the northwest. These coals are not workable over any considerable area in the rest of the county, unless it be in Stockton Township.

South of Greene County these coals are generally less than 3 feet thick. The following are the main areas where workable: Around Raglesville, Daviess County, there are a few square miles where coal III is found 3 to 5 feet thick; it occurs mainly above drainage level. Around Cannelburg coal III is 3 to 6 feet thick, and has an extent of a few square miles; the upper half is a good quality of cannel coal.

Montgomery field, in the central part of Daviess County, probably contains a score of square miles, over a large share of which coal IV will run 3 feet or more in thickness. This bed has a clay band near the center throughout the whole of this area.

South of White River coal II appears. From this locality to the Ohio River coals II, III, and IV are workable in numerous small basins a few hundred acres in extent, notably around Jasper, Huntingburg, in Boone and Harbison townships of Dubois County; in the "Knobs" of Spencer County; south of St. Meinrad; near New Boston and on Crooked Creek; west of Maxville; near Buffaloville and Lincoln City, and near Newtonville. Around Troy and Cannelton, in Perry County, coal II, of a pockety but workable nature, originally covered several square miles, but a large part of this has been exhausted.

Workable coal of upper part of Wabash group (Divisions V (in part), VI, VII, and VIII of Indiana Survey).—What is commonly called the bituminous field in Indiana, in contradistinction to the block coal field, covers that portion of the Indiana field lying west of the area just considered.

Beginning at the north, coal VI first attains workable thickness along the Big Vermilion River, northwest of Eugene, but to the south nearly to Clinton it is pockety and not usually workable. Coal VII is 4 to 5 feet thick around a considerable area at the "Horseshoe" on the Little Vermilion River. It appears to be more or less continuously workable within the area of its outcrop as far south as Knox County. It ranges from 3 to 6 feet in thickness as far as Terre Haute, but south of that point is much reduced by sandstone rolls which cut into the roof. It is well above drainage level in Vermilion County, but is below drainage level along the Wabash from the southern border of Vermilion County nearly to Terre Haute. It outcrops along the east side of Vigo, Sullivan, and Knox counties, but is nearly 400 feet below the surface at Vincennes. South of Knox County coal VII is workable only in places.

Coal VIII is found workable in the southwest corner of Vermilion County and the northwest part of Vigo County on Coal Creek.

Coal VI becomes workable north of Clinton and is from 5 to 8 feet thick over southern Vermilion, southwestern Parke, western Clay, and most of Vigo counties. It underlies Sullivan and northern Knox counties, apparently as a continuous bed, uniformly averaging about 6 feet in thickness. From its outcrop it dips west so as to be from 150 to 250 feet deep in the center of Vigo, Sullivan, and Knox counties, and from 300 to 400 feet deep along the State line. South of Knox County it becomes pockety and runs out before the Ohio is reached.

Coal V becomes one of the "bituminous" coals from Greene County southward. It is workable in the region of its outcrop in the western edge of Greene and eastern edge of Sullivan and Knox counties, having a thickness of from 5 to 9 feet or more, averaging at least 6 feet. As is usual, it is characterized by a roof of black sheety shale overlain by limestone. Though often of good thickness, it is pockety along the eastern edge of Knox County, but sets in again at White River and appears to form a continuous sheet under western Pike and Warrick counties, all of Gibson and Vanderburg counties, and possibly under Posey County. It starts in at White River with a thickness of 8 to 10 feet, but southward becomes gradually reduced to 4 feet along the Ohio. From its outcrop the dip gives it a depth of 400 feet at Princeton and 250 feet at Evansville, the difference in altitude of the two places largely making up the difference.

Area of the Merom group.—The rocks of this group occupy a small area in southwestern Vigo County, the western half of Sullivan, Knox, Gibson, and Vanderburg counties, and all of Posey County. The group itself contains no workable coal, and in the region in question the workable coals lie at least 250 feet below the surface and reach a much greater depth farther west. The scarcity of deep wells in this region makes it difficult to obtain definite knowledge of this area, but the little information at hand suggests that coal VI may be workable under most of the northern part of the area, and coal V under the southern part.

ILLINOIS.

The workable coals of Illinois are those designated 2, 3, 4, 5, 6, and 7 by the geological survey of Illinois. These numbers are used in the present paper as purely local terms, because they have a certain currency in this field, and their use should not be taken as implying correlation. Until the coal beds of the State shall have been traced out in detail it will be hazardous to assert, for example, that coal 7 at Danville and coal 7 at Shawneetown occupy the same horizon. Wherever possible, local names will be used in addition to the numbers, the numbers being retained for their local value and to show the assumed relative position of the coals in question. At present the only areal divisions of this field which can be made are the areas of outcrop, (1) of the Upper or Barren Coal Measures, and (2) of the Lower or Productive Measures. The latter includes the basal sandstone, which, with the incomplete data at hand, can not be separately shown on the map.

Beginning at the northeast, the Danville field may first be considered. Two coal beds of workable thickness occur in this field, the Danville coal, correlated as coal No. 7 of the Illinois section, and the Grape Creek coal, or coal No. 6. Both of these beds are developed west of the (Wabash) Vermilion River. In the developed portion of the field the Grape Creek coal has a thickness of 6 feet or more, large areas south of Danville showing that or greater thickness. The Danville bed lies about 80 feet above the Grape Creek bed. It has a thickness of 5 feet to 7 feet 6 inches over a large area west of Danville, but thins toward the south. These coals outcrop along the valley of (Wabash) Vermilion River, but rapidly dip below drainage level on passing up the Middle Fork, reaching a depth of 200 feet or more at Muncie and Fairmount. At only about a dozen of the mines of this district is the coal more than 100 feet in depth, and at many of them its depth is less than 50 feet. At most of the small mines, and at a few of the large ones, the coal is mined by stripping.

Northwest of Danville there are two fields in the first inspection district. These are known as the Wilmington and Streator fields. The first includes portions of Will, Grundy, and Lasalle counties. The coal worked is known as the Wilmington coal and is correlated as coal No. 2. It is a thin, irregular coal, averaging only about 3 feet in thickness, though increasing to 6 feet in places. This coal underlies, so far as known, only a few square miles of Will County, and about two-thirds of Grundy County. In these two counties it occurs near the surface, most of the commercial mines working it being less than 90 feet deep, and none over 210 feet deep. The deepest mines are in the south end of Grundy County. This coal is found in the northwest corner of Kankakee County at a depth of 160 feet; in Livingston County at depths of 64 feet or less; in the south half of Lasalle County at depths of 550 feet or less. Its thickness over the last three counties is about the same as in the area of its greatest development, but on account of its greater depth it is worked at only a few places in these counties. The largest mine, however, in Livingston County at Pontiac, is working it at a depth of 464 feet.

The Streator coal, or coal No. 7, is worked in Lasalle, Livingston, and Kankakee counties. It is much thicker than No. 2, ranging from 4 to 8 feet, with an average probably of about 5 feet. It ranges in depth from 65 feet to nearly 200 feet, averaging a little over 100 feet at the larger mines. Most of the local mines find coal at depths of 40 to 70 feet, the coal usually being thin, from 2 feet 3 inches to 3 feet 6 inches. West of the line of folding or faulting which passes near Lasalle the coal is deeper, being from 375 to 500 feet below the surface; it averages 3 feet 6 inches in thickness at most of the mines. This is probably coal No. 2, or the "third vein," though coal No. 5 is worked in this district at the N. and H. zinc works at a depth of 300 feet. This bed is 117 feet deep at Clark City, just over the line in Kankakee County. At a few points workable coals are found that are correlated as Nos. 5 and 6 of the Illinois section. Coal No. 5 in Lasalle County ranges from 3½ to 5 feet in thickness.

Passing westward into the second inspection district, less definite information regarding the coals is available. So far as correlations have been made, the principal coal worked appears to be the same as coal No. 2, or the Wilmington bed of the first district. Its thickness is about 3½ feet, as in the first district, and its depth as much as 600 feet at the point where it passes under the Upper Measures. On account of its quality it is in many cases worked in preference to Nos. 5 and 7, which are 4 feet or more in thickness and lie above it. Coal No. 5 is about 150 feet above No. 2, while No. 7 is 50 feet higher still. In the eastern part of Bureau County coal No. 2 is from 300 to 500 feet below the surface and 3½ feet in thickness. In the central and western portions of the county small mines work a 4½-foot bed at slight depths. Similar conditions exist in Marshall and Woodford counties, where coal No. 2, with a thickness of 2½ feet to 3 feet 10 inches, is worked at depths varying from 375 to 555 feet, while farther west a surface bed 4 feet thick is worked by small mines.

The Kewanee coal of Henry County, sometimes correlated as coal

No. 6, is 4 feet thick and less than 100 feet deep. In Stark County coal No. 6 is from 2½ to 6 feet thick and varies in depth from outcrop to 130 feet. Coal No. 4 underlies most of this county with a thickness of 4 to 6 feet. In Peoria County No. 4 is 4 feet in thickness and outcrops along the river, while in the river bottoms No. 2 is reported 4 feet thick at a depth of 120 feet, and No. 1 is 3 feet thick at a depth of 235 feet. Coal No. 5 is worked in the higher ground with a cover of 50 to 100 feet; it has a thickness of 4 to 4½ feet. Away from the river the depth to coal No. 2 is often over 250 feet. In Rock Island and Mercer counties the coals are shallow, seldom being 100 feet deep, though one mine has a depth of over 200 feet. The worked coals range in thickness from 3 feet to 3 feet 8 inches in Rock Island County, and from 2½ feet to 4 feet in Mercer County.

In the portions of the Third inspection district which lie west and soutwest of Peoria, coals Nos. 4, 5, 6, and 7 are workable; of these coal No. 4 is probably the most persistent. It varies from 3 to 6 feet in thickness, averaging about 4½ feet. Coal No. 6 is of about equal value where found, while coal No. 5 is more local in workable development. Coal No. 7 appears to have been eroded from most of the area. All of the worked coals in this area lie at depths of less than 200 feet from the surface, and generally at less than 100 feet. In Schuyler County No. 4 is found only in the highest parts of the county, and never at a greater depth than 75 feet. In Fulton County, which furnishes most of the coal mined in this district, coals 4, 5, and 6 underlie about seven townships in its central and northeastern portions, while Nos. 1, 2, and 3, varying from 2 to 4 feet in thickness, are found in the southern and western portions. Knox County has a 4-foot coal with usually less than 100 feet of cover. The counties west of these—Warren, Henderson, McDonough, Hancock, and Brown—furnish only coals with a thickness of 2 to 3 feet at depths of less than 100 feet, in the southern and western portions. Nos. 1 and 2 continue southward into the Fifth district; they outcrop along the lower part of the Illinois River with a thickness of 3 to 4 feet. The Productive measures outcrop in the western part of the Fourth district. In Tazewell County, coal No. 4 is 4½ feet thick, and outcrops along the river. In Menard County, No. 5, with a thickness of 5 feet, is mined at depths of 50 to 200 feet. The coals of Cass County are less than 3 feet thick and are worked at depths up to 215 feet.

From the latitude of Springfield southward, the outcrop of the Productive measures becomes comparatively narrow, the eastward dip becoming steeper, so that each of the various coals is near the surface within a comparatively narrow belt. They are mined at slight depths, usually less than 100 feet. In the river counties they range from 2 to 5 feet in thickness, but are generally less than 3 feet. The bulk of the worked coal of Sangamon and Macoupin counties is taken from under the outcrop of the Upper Coal Measures. A few mines in these counties, however, reach coal No. 5 at depths of 50 to 200 feet, where it has a thickness of 5 to 7 feet. In Madison and St. Clair counties the main coal worked is known as the Belleville bed. It is correlated as coal No 6. Coal No 7, of almost if not quite equal thickness, lies but a short distance above. These coals have each a thickness ranging from 5½ to 7½ feet, with an average of over 6 feet. They are mined at depths varying from 50 to 300 feet, most of the large mines having a depth of 100 to 200 feet. They underlie all of the uplands of Madison County and three-fourths (450 square miles) of St. Clair County.

The area within which the Productive measures come to the surface continues around the south end of the field with a width of from 20 to 30 miles. Along its southern edge only the lower coals are exposed, usually with a thickness of less than 3 feet. Within the northern portion of this strip, coals 4, 5, 6, and 7 are workable at depths of less than 300 feet. Of these, No. 5 varies from 5 to 7 feet in thickness where worked; No. 6 from 8 feet down; and No. 7 from 10 feet down. Coal No. 6, or the Duquain coal, averages about 6 feet in the mines. It is extensively mined in Randolph and Perry counties at depths up to 200 feet. A 9-foot bed is worked at St. Johns at a depth of 300 feet; coal No. 6 is only 28 feet deep at a neighboring mine. At Coulterville, in Randolph County, a 6-foot bed is found at 370 feet. The latter is probably a lower coal than the bed worked at St. Johns. Coal No 7 varies from about 4 feet in Gallatin County to an average of 9 feet in many of the mines of Williamson County, where it is known as the Carterville bed. This coal underlies the north half of this county, at depths up to 150 feet. Coal No. 5 lies 100 to 150 feet deeper. In Jackson County the Big Muddy coal, probably coal No. 5, is from 5 to 7 feet thick, with an average thickness in the mines of over 6 feet. In depth it varies from 20 to 166 feet. In Johnson County a 3-foot-4-inch surface coal is mined. In Saline County, coal No. 5 is found at 144 feet at Harrisburg, with a thickness of 6 to 7 feet. A 3- to 5-foot coal (coal No. 7?) outcrops over the county. In Gallatin County the coals worked range from 4 feet to 4 feet 10 inches, at depths of less than 100 feet.

The area of outcrop of the Upper or Barren Coal Measures occupies a large area, extending from Lasalle southeastward, as shown on the map. At the time of the old geological survey of the State, the coal-producing possibility of this area was practically an unknown factor, deep drilling having been undertaken on only a limited scale. Investigation has shown that the western portion at least of this area is underlain by workable coal and suggests that workable coal probably underlies most of it. Though several workable beds have been found in the western part of this area, mining is confined almost entirely to what is considered a single bed, correlated as coal No. 5. Nos. 2, 3, 4, and 6, however, are also worked in a few places. No. 5 is known as the Pana and also as the Springfield coal. It is reported as reaching a thickness of 11 feet. Its average will probably be over 5 feet, while it is doubtless much thicker in some places. Thus, in Christian County it will average about 7½ feet. The evidence at present available indicates that the bed is continuous over most of this territory beneath the Barren measures. In depth it ranges from 250 to 300 feet at Springfield to 871 feet at Kinmundy, Marion County (Coal No. 2 is worked at 1,003 feet at Assumption). It is usually over 300 feet deep.

In McLean County this coal varies in thickness from 3 to 5½ feet, and in depth from 275 feet at the northeast to 540 feet at Bloomington. In Logan County it is from 4 to 5⅓ feet thick and 267 to 360 feet deep. In Macon County it is from 4 to 5 feet thick, and from 365 feet deep on the west to over 600 feet at Decatur. In Sangamon County the coal varies in thickness from 5⅓ to 7½ feet, and in depth from 150 feet on the west to 300 feet on the east. In Christian County the coal averages 7½ feet in thickness. It is 365 feet deep at Edinburg; 462 feet at Taylorville; 720 feet at Pana. At Assumption a 3 foot 6 inch bed is worked at a depth of 1,004 feet. This coal ranges here from 3 to 11 feet in thickness. In Macoupin County the coal ranges from 6 to 8 feet in thickness, averaging nearly 8 feet at Mount Olive and Virden; it is mined at depths of 300 to 435 feet. In Montgomery County the depth varies from 440 feet at Hillsboro to 684 feet at Litchfield, and the thickness of the coal is from 6 to 8 feet. A bed 3½ feet thick is worked at Litchfield at a depth of 500 feet. The coal is 618 feet deep just over the Shelby County line at Moweaqua. In Bond County the coal is 4⅓ to 7½ feet in thickness and from 380 to 490 feet deep. In Clinton County it is from 323 to 400 feet deep, and probably corresponds to Nos. 6 and 7; of these, the 4½-foot coal at Trenton is thought to be coal No. 7, and the 7- to 8-foot coal found elsewhere is supposed to be coal No. 6. In Marion County the coal is correlated as coal No. 5; it is from 4 to 7 feet thick and varies from 576 feet in depth at Centralia to 885 feet at Salem. In Washington County coal No. 6, or the Duquoin coal, is 5½ feet thick and from 296 to 423 feet deep. In Jefferson County probably the same coal is 4 feet 10 inches thick at Mount Vernon and 812 feet deep. In all of these counties many small mines are working the thin beds of the Upper Measures on a small scale, the coal usually varying from 2 feet to 2½ feet in thickness.

There remains a large area in the eastern part of the State in which the outcropping rocks belong to the Upper Measures, and the workable coal if such exists, lies deep, probably all of it more than 300 to 500 feet. There are at present no working mines in this area, and over most of it deep drilling has not yet determined whether or not it contains workable coal. Judging, however, by what is found both to the east and to the west it seems a fair inference that a large part, possibly most, of this region is underlain by workable coal. This area includes the two rows of counties next the Indiana line south of Kankakee County, except Vermilion County, down to and including White County; and in addition, Platt, Moultrie, Fayette, Effingham, Clay, and Wayne counties. What drilling has been done in these counties indicates that workable coal certainly occurs in several of them and is probably absent from others.

KENTUCKY.

The workable coal of Kentucky is confined mainly to two beds, designated Nos. 9 and 11 by the Kentucky State survey. Of these, No. 9 is the more persistent and furnishes by far the largest part of the product of this field, probably 75 per cent or more. It occupies the whole or parts of seven or eight counties, including all of the field except its eastern portion and the southern or southwestern edge. It is also absent from a few small tracts where it has been cut out by reason of irregularities in the structure of the field. This bed has an average thickness of 5 feet, seldom varying more than 6 inches from the average. As a rule it is found at depths of less than 200 feet, though at Eureka, Hopkins County, it is reported to be 400 feet below the surface.

From 40 to 100 feet above No. 9 is found the next most important bed of Kentucky, namely, coal No. 11. This bed is much more irregular than No. 9, but at most of the mines at which it is worked it has a thickness of 6 feet or over. At Eureka it reaches a thickness of 7½ feet. It is reported as always having a clay parting one-fourth of an inch to 2 or 3 inches thick, and is much disturbed by rolls, clay slips, etc. As a rule, this coal is found at shallow depths, usually outcropping at the surface and extending to depths of less than 100 feet. This is supposed to be the coal worked at Henderson, at a depth of 185 feet. At Eureka it is 300 feet deep. About 25 feet above coal 11 is found coal 12. This is thin toward the west, but becomes of some importance in the center of the field. In Webster, Hopkins, McLean and Muhlenberg counties this bed is from 3 to 6 feet thick, the maximum thickness occurring in the last-named county. Its position in the ground is sufficiently well indicated by its relation tc coal 11. Among the lower coals which occur around the borders of the field the following are workable: Near Dekoven, in Union County, two beds are worked known as the "3-foot bed," probably coal No. 6, and the "4-foot bed," probably No. 5. The last-named bed is known as the Lewisport coal in Hancock County, where it has a thickness of 3 or 4 feet, or more. Along the eastern border of the field the principal bed is known as the "Main coal" at Hawesville, and is also worked at Mud

River, Empire, and Aberdeen. In Edmonson County the same bed is known as the "Main Nolin coal." Its thickness is variable, reaching a maximum of 4½ feet. It also frequently carries considerable cannel coal.

CHARACTER OF THE COAL.

The fuel value of any coal is determined by chemical analysis, by steam boiler tests, and by results achieved in actual practice.

ANALYSES.

Hundreds of analyses have been made of the coal in this field, but so far as possible only those are given in the accompanying tables which are believed to be based on properly sampled material, so as to give average results.

The following table is from the Twenty-first Annual Report of the State Geologist of Indiana, page 99.

Analyses of several Pittsburg and West Virginia coals were made at the same time, and the results are inserted in the table for comparison.

Analyses of coal from Eastern Interior coal field.

Number.	County.	Name of coal and owners.	Total combustible matter.	Volatile combustible matter.	Fixed carbon.	Moisture.	Ash.	Sulphur.	Evaporative effect—pounds of water per pound of coal.	Fuel ratio = fixed carbon ÷ Volatile combustible matter.
1	Vanderburgh ..	Sunnyside Coal and Coke Company, Evansville.	86.73	38.59	48.14	6.44	6.83	1.85	12.9	1.25
2	Warrick........	Deforest mine............	84.16	39.09	45.07	6.08	9.76	2.14	12.5	1.15
3	Knox..........	Edwardsport coal mine, Edwardsport Coal and Mining Company.	82.03	36.00	46.03	8.75	9.22	3.08	12.1	1.28
4	.....do..........	Bicknel mine, Bicknel Coal Company.	83.76	35.22	48.54	7.61	8.63	1.67	12.5	1.38
5	Daviess........	Cabel and Kauffmann....	87.15	37.99	49.16	6.50	6.35	1.85	13.0	1.30
6	Sullivan	Star City.................	87.30	38.53	48.77	9.40	3.30	1.23	13.0	1.27
7	.....do..........	Alum Cave...............	84.77	42.60	42.17	6.49	8.74	3.18	12.5	0.99
8	Greene.........	Buckeye or Fluhart, Linton Coal and Mining Company.	86.79	35.69	51.10	7.81	5.40	0.72	13.0	1.43
9	.....do.........	Summit mine, Dugger and Neil Coal Company.	87.54	35.30	52.24	7.44	5.02	0.61	13.1	1.48
10	.....do..........	Island City mine No. 1, Island City Coal Company.	86.47	35.97	50.50	7.12	6.41	0.84	13.0	1.40
11	Vigo	Ray mine, Seeleyville, Vigo County Coal Company.	84.46	40.25	44.21	7.57	7.97	4.01	12.4	1.10
12	Clay	Gart No. 5 shaft, Brazil Block Coal Company.	85.27	36.11	49.16	11.20	3.53	0.62	12.8	1.36
13	.....do.........	Brazil Block No. 1 shaft, Brazil Block Coal Company.	85.12	35.16	49.96	13.82	1.06	1.47	12.9	1.42

Analyses of coal from Eastern Interior coal field—Continued.

Number.	County.	Name of coal and owners.	Total combustible matter.	Volatile combustible matter.	Fixed carbon.	Moisture.	Ash.	Sulphur.	Evaporative effect—pounds of water per pound of coal.	Fuel ratio = fixed carbon ÷ Volatile combustible matter.
14	Clay	Eureka mine No. 1, Carbon, Eureka Block Coal Company.	86.74	36.32	50.42	9.80	3.46	0.34	13.1	1.39
15	....do	Crawford No. 3 mine, Crawford Coal Company.	84.58	36.34	48.24	11.26	4.16	0.56	12.7	1.33
16	....do	Columbia No. 2 mine, Teller, McLelland & Company.	89.52	36.75	52.77	7.47	3.01	0.57	13.4	1.44
17	Owen	Lancaster No. 4 mine	83.85	36.45	47.40	12.73	3.42	0.55	12.6	1.30
18	Parke	McIntosh No. 1 mine, near Diamond, I. McIntosh & Company.	87.70	36.69	51.01	8.21	4.09	0.95	13.1	1.39
19	....do	Cox No. 3 shaft, "bituminous," Brazil Block Coal Company.	88.33	41.88	46.45	6.49	5.18	2.93	13.1	1.11
20	Pittsburg coals.	Beck's Run, first pool, Hays Coal Company.	96.06	36.01	60.05	2.09	1.85	0.64	14.6	1.67
21	....do	Anchor, fourth pool, Beaumont Coal Company.	89.84	35.30	54.54	1.30	8.86	0.45	13.5	1.55
22	....do	Caledonia, fourth pool, T. J. Wood.	90.26	35.22	55.04	1.35	8.39	0.69	13.5	1.56
23	....do	Stony Hill, fourth pool, John D. Nixon.	92.74	35.46	57.28	1.11	6.15	0.56	13.9	1.62
24	....do	Little Redstone, fourth pool, Little Redstone Coal Company.	91.08	35.88	55.20	0.98	7.94	0.82	13.7	1.54
25	West Virginia coals.	Raymond, Marmet Smith Coal and Mining Company.	91.16	40.14	51.02	3.20	5.64	2.25	13.6	1.27
26	....do	Belmont, Belmont Coal Company, Belmont, W. Va.	90.04	37.84	52.20	1.45	8.51	0.46	13.5	1.38
		Average of Indiana coals.	86.36	38.22	48.14	8.45	5.61	1.52	12.7	1.26

Nos. 12 to 18, inclusive, are of block coal; and Nos. 8 to 10, inclusive, are of semiblock. The small amount of sulphur in these two varieties as compared with the bituminous coals of Indiana is noteworthy.

As compared with the well-known Pittsburg coal, it is seen that the Indiana coals run a little higher in the percentage of volatile combustible matter, from 3 to 9 per cent lower in fixed carbon, and from 4 to 6 per cent lower in total combustible matter. The quantity of moisture in the Indiana coal is much greater than in the eastern coals, while the ash of the former is less than the latter. In quantity of sulphur the Indiana block and semiblock coals are about on a par with the eastern coals, while the Indiana "bituminous" coals contain much more. Several hundred analyses of Indiana coal were made by the earlier State geologists, but as they were of picked and partly dried hand specimens they are not considered of value in this connection.

In the first volume of the reports of the Kentucky survey under Professor Shaler 110 analyses of properly sampled coals of Kentucky and neighboring States were reported. Thirty-three of these were from the western field and 12 from Ohio, Illinois, and Indiana. Those from Indiana were from the block-coal field; and the Illinois coals, as well as the Ohio coals, are stated to have been the best coals of those States. All of these coals are said to be of the splint, dry, or semi-block variety. The results of these analyses are contained in the following table:

Analyses of coal from Eastern Interior coal field.[a]

County.	Number of analyses.	Specific gravity.	Volatile combustible matter.	Fixed carbon.	Ash.	Sulphur.	Fuel ratio.
Butler, Ky	1	1.378	30.66	54.94	11.00	2.544	1.71
Edmonson, Ky	8	1.360	34.01	52.34	10.56	3.312	1.54
Grayson, Ky	8	1.385	31.17	49.78	14.38	2.083	1.60
Hopkins, Ky	2	1.385	32.95	52.55	11.20	5.019	1.59
Muhlenburg, Ky	11	1.312	36.42	53.26	6.74	2.949	1.46
Ohio, Ky	3	1.362	34.90	53.77	8.16	3.103	1.54
Average of—							
Kentucky coals	33	1.3636	33.70	52.77	10.34	3.166	1.57
Illinois coals	2	1.310	31.95	59.06	5.96	1.924	1.85
Indiana coals	3	1.313	35.93	54.24	7.23	1.946	1.51
Ohio coals	7	1.327	34.51	55.17	6.43	1.494	1.60

As compared with the best Indiana coals, those from Kentucky show a larger percentage of ash and sulphur and a smaller percentage of gas and fixed carbon. They are, therefore, apparently inferior to either the Indiana or the Illinois coals. Compared, however, with the averages of the Indiana coal given from the reports of that State, it would appear that on the whole the Kentucky coals are richer in fixed carbon, but poorer in gas, with 86.47 per cent of combustible matter against 86.36 per cent for the Indiana coals. The advantage of the Kentucky coals in their greater amount of fixed carbon is largely offset by the greater quantity of ash and sulphur which they carry.

Aside from those given above no analyses of Illinois coal properly sampled and properly analyzed could be found. A number of

[a] Geol. Surv. Kentucky, Vol. I, new series, p. 147.

analyses have been summarized from the Illinois reports and are given below:

Analyses of Illinois coal.

Mine and coal.	Moisture.	Specific gravity.	Volatile combustible matter.	Fixed carbon.	Ash.	Fuel ratio.
St. Clair County, Belleville mines, coal 7[a]	5.50	1.293	39.50	54.60	5.40	1.38
Madison County, various mines, coal 7[b]	8.70	1.296	35.39	54.19	5.07	1.53
Fulton County, coal 4	5.18	......	30.06	57.25	7.51	1.90
Fulton County, coal 6[c]	5.94	......	30.80	57.85	5.38	1.88
Grundy County, coal 2 ? (4 analyses)[d]	10.09	......	27.00	57.05	5.25	2.11
Vermilion County, coal 7 (several analyses)[e]	7.13	1.2563	41.85	51.57	7.25	1.23
Vermilion County, coal 6 (2 analyses.)[f]	7.70	1.312	36.83	55.90	6.00	1.51
Randolph County, coal 7 (5 analyses)[g]	7.55	......	30.19	55.44	4.94	1.83
Marion County, coal 5 (2 analyses)[h]	8.36	......	30.14	48.35	12.83	1.60
Jackson County, Big Muddy coal[i]	6.50	1.293	31.20	60.80	1.50	1.91

[a] Geol. Survey Illinois, Vol. I, p. 309.
[b] Geol. Survey Illinois, Vol. I, p. 319.
[c] Geol. Survey Illinois, Vol. IV, p. 104.
[d] Geol. Survey Illinois, Vol. I, p. 276.
[e] Geol. Survey Illinois, Vol. IV, p. 257.
[f] Geol. Survey Illinois, Vol. IV, p. 259.
[g] Geol. Survey Illinois, Vol. III, p. 574.
[h] Geol. Survey Illinois, Vol. VIII, p. 42.
[i] Geol. Survey Illinois, Vol. III, p. 77.

In addition to the above analyses taken from official sources, the following have been reported by mine owners. While they have the advantage of being recent, and usually showing the amount of sulphur, as a rule nothing is known as to how the samples were obtained, and therefore how nearly the results represent the average of the fuel as it actually reaches the market:

Analyses of Illinois coal.

Mine.	Number of coal bed.	Moisture.	Fixed carbon.	Volatile combustible matter.	Ash.	Sulphur.	Authority.
1. Oglesby, La Salle County.	2	12.12	49.32	30.84	7.72	....	"By a customer."
2. Braceville, Grundy County.	2	2.27	33.60	46.33	11.80	6.00	
3. Greenview, Menard County.	5	10.94	41.21	39.20	8.65	3.10	S. W. Parr, U. of Ill.
4. Dumfermline, Fulton County.	5	6.65	43.25	40.44	9.66	1.52	J. S. Cary, World's Fair.
5. Lincoln, Logan County.	5	5.60	46.85	38.80	6.15	2.60	J. S. Cary, World's Fair.

Analyses of Illinois coal—Continued.

Mine.	Number of coal bed.	Moisture.	Fixed carbon.	Volatile combustible matter.	Ash.	Sulphur.	Authority.
6. Penwell, Pana, Christian County.	5	6.30	44.21	41.26	5.15	3.08	L. C. Boyce, World's Fair.
7. Springside, Pana, Christian County.	5	1.94	58.32	36.59	2.24	.90	B. L. Moore, Chicago.
8. Moweaqua, Shelby County.	5	8.00	46.00	39.53	6.47	2.50	S. W. Pau, Champaign, Ill.
9. Hillsboro, Montgomery County.	5	9.05	43.47	41.07	3.35	3.06	J. S. Cary, World's Fair.
10. Junction, Sangamon County.	5	9.11	46.70	34.65	11.95	....	L. P. Breckenridge.
11. Sholl Bros., Peoria County.	5	3.44	74.36	19.16	1.22	1.82	
12. Edwards, Peoria County.	5	1.90	43.62	34.48	20.00	....	Chicago, Burlington and Quincy Rwy. Co.
13. Herrin, Williamson County.	6	6.29	54.91	30.54	8.26	1.52	A. Chonoent & Bros.
14. Sunnyside, Williamson County.	6	2.20	54.40	38.34	5.06	1.97	
15. Marion, Williamson County.	7	5.70	56.39	32.00	5.91	1.08	
16. O'Fallon, St. Clair County.	7	1.45	54.80	37.25	6.50	1.24	Cunningham & Co., Cin. O.

A comparison of the two analyses of Pana coal Nos. 6 and 7 shows what a difference in results may be obtained by selecting specimens for analysis, and at the same time shows how little value can be assigned to analyses reported under such circumstances, no matter how well sampled and analyzed.

Summarizing all the facts at hand, it appears that the lower coals of this field, usually occurring about its margin, while thinner and much more irregular than the higher coals, are of rather better quality; and that of these what are known as the Brazil block coals will probably make a little the best showing. The thinness of these lower coals makes them somewhat more expensive to mine than the higher coals. Considered from the commercial standpoint this somewhat offsets their higher grade.

Most of the Western coals run high in gas, which puts them at a disadvantage in actual present practice as compared with coals of the Appalachian field having about the same total amount of combustible matter. This relation is shown by a comparison of the fuel ratios of coals from various fields given in the following table. The fuel ratio is obtained by dividing the percentage of the total combustible matter, which consists of fixed carbon, by the percentage of the volatile hydrocarbons.

Fuel ratios of coals from the Eastern Interior and other fields.

Indiana coals, average of 20 analyses	1.26
Missouri coal (Rich Hill)	1.29
Illinois coal (Belleville)	1.32
Westmoreland, Pennsylvania, coal-gas coal	1.46
Western Kentucky coals	1.53
Connellsville coal, Pennsylvania, standard coking coal	1.98
Pocahontas coal, West Virginia, semibituminous coking	3.95
Bernice coal, Pennsylvania, semianthracite	10.30
Wilkesbarre, Pennsylvania, anthracite	19.33

BOILER TESTS.

The following table shows the result of boiler tests. The tests were made under the same conditions in each case of coals from this field and from various other fields for comparison. The figures represent the pounds of water evaporated from and at 212° per pound of fuel. No comparisons can be made, except between the results of a single set of experiments:

Boiler tests of coals from the Eastern Interior and other fields.

Coal.	Johnson.[a]	Blake.[b]	Meigs, Meigs boiler.[c]	Meigs, Little Giant boiler.[c]	Babcock and Wilcox boilers.[d]	Landreth.[e]	Anderson.[f]
Indiana block, Indiana	......	7.21	......	......	9.47	......	......
Cannelton, Ind	7.34	......	7.32	7.12	......	......	......
Run of mines, Illinois	......	......	......	......	9.49	......	......
Staunton, Ill	......	......	......	......	5.09	......	......
"No. 11" (western field), Kentucky	......	......	......	......	......	......	5.72
"No. 9" (western field), Kentucky	......	......	......	......	......	6.73	5.22
Reynolds, Ohio County (western field), Ky	......	......	......	......	......	6.45	4.90
Jellico (eastern field), Ky	......	......	......	......	......	7.45	6.10
Laurel (eastern field), Ky	......	......	......	......	......	7.41	5.94
Mud River (eastern field), Ky	......	......	......	......	......	6.89	......
Coalton coal (eastern field), Kentucky	......	......	......	......	......	......	4.78

[a] Experiments on the evaporative power and other properties of American coal: Rept. to Sec. of Navy, 1844, by Walter R. Johnson.

[b] The evaporative power of Kansas coals, by L. T. Blake: Sixth Biennial Rept. Kansas State Board of Agriculture.

[c] Rept. on fuel for the Army, by Quartermaster-General Meigs, 1882.

[d] Evaporative power of bituminous coal, by William Kent: Trans. Am. Soc. Mech. Engs., 1883.

[e] Rept. Kentucky Insp. Mines, 1888, and 1895, p. 208.

[f] Same, 1895, p. 214.

Boiler tests of coals from the Eastern Interior and other fields—Continued.

Coal.	John-son.	Blake.	Meigs, Meigs boiler.	Meigs, Little Giant boiler.	Bab-cock and Wilcox boil-ers.	Land-reth.	Ander-son.
Peach Orchard (eastern field), Ky	------	------	------	------	------	------	6.15
Avent-Beattyville (eastern field), Ky	------	------	------	------	------	------	6.33
Altamont (eastern field), Ky	------	------	------	------	------	------	5.94
Pittsburg, Laurel County (eastern field), Ky	------	------	------	------	------	------	6.99
Pittsburg, Pa	8.20	------	8.78	6.74	10.20	------	------
Glenmary, Tenn	------	------	------	------	------	------	5.89
Kanawha, W. Va	------	------	------	------	------	------	7.37
Kansas coals	------	6.50	------	------	------	------	------
Leavenworth, Kans	------	------	6.49	6.42	------	------	------
McAlester, Ind. T	------	------	7.68	6.96	------	------	------
San Antonio, Tex	------	------	------	4.46	------	------	------

In 1899 an extensive correspondence was carried on by the State survey of Indiana relative to the fuel value of Indiana coals in actual practice as compared with the eastern coals with which they came into competition. The results were briefly stated as follows:

First, with present practice, Indiana coal will average from 5 to 15 per cent lower in heating power than Pittsburg or West Virginia coal; second, without regard to cost, some of the Indiana coals are better than some of the eastern coals shipped into this State; third, if Indiana slack or run-of-mine (which usually contains a larger percentage of slack than eastern coals) be compared with eastern coals in the same form, the heat value will be still more in favor of the eastern coals. This is probably due, as stated above, to the oxidation of the volatile hydrocarbons in the fine coals by weathering; fourth, Indiana block coal comes nearer Pittsburg coal for most purposes than other western coals.

COKING VALUE.

A study of the analyses of coals given above shows that the Indiana and Illinois coals contain on an average about 55 per cent of coke, while the analyses of Kentucky coals indicate that they will yield over 60 per cent of coke. In practice the results differ somewhat from these figures, the actual yield of coke being below the theoretical yield. However, as much or most of the coal used is first washed, the results in practice may be much better than indicated by the analyses of unwashed coal. Thus, in Illinois in 1897 the yield of unwashed coal in coke was only 43 per cent, while from 1892 to 1896 the yield from washed coal ran from 57.9 to 66.7 per cent. In Indiana the average from 1886 to 1897 was 47.9 per cent, most of which was from washed coal. In Kentucky the average from 1880 to 1897 was 52.8 per cent, mostly from washed slack. A study of the statistics of coke production in Indiana and Illinois shows that those States are not succeeding as coke producers. In Illinois the production of coke declined from 14,800 tons in 1881 to 1,549 tons in 1897, and the number of establishments from 9 in 1884–1886 to 2 in 1897. In Indiana the production declined from 17,658 tons in 1887 to 2,904 tons in 1897. On the other hand, the production in Kentucky has risen from 2,223 tons in 1884 to 72,975 tons in 1900, of which 36,864 tons were produced in the western field. The difficulty in Indiana and Illinois seems to be that the coals in those States most suitable from the standpoint of purity are of the splint or noncoking variety, while the coking coals, as a rule, run too high in sulphur. Also in a large number of cases the resulting coke has not as desirable physical characteristics as the eastern coke with which it comes into competition. Hence, while these States contain true coking coals, from which good coke has been produced, the coke is not so good as that from Pennsylvania, and at the slight difference in price can not compete on a large scale.

Turning to the portion of the Eastern Interior field which lies in western Kentucky, the following table, from the Sixteenth Annual Report of this Survey, is of interest as "exhibiting the physical and chemical properties of St. Bernard coke (western field) as compared with Connellsville."

Comparison of Connellsville and St. Bernard coke.

	Locality.	
	Standard coke, Connellsville.[a]	St. Bernard, Kentucky.[b]
Grams in 1 cubic inch:		
Dry	12.46	12.87
Wet	20.25	20.92
Pounds in 1 cubic foot:		
Dry	47.47	49.03
Wet	77.15	79.70
Percentage:		
Dry	61.53	63.50
Wet	38.47	36.41
Compressing strength per cubic inch, one-fourth ultimate strength	284	328
Height of furnace charge supported without crushing	114	131
Order in cellular space	1	1
Hardness	3.5	3.2
Specific gravity	1.500	1.400

[a] Authority, Prof. A. S. McCreath. [b] Authority, T. T. Morrell.

Comparison of Connellsville and St. Bernard coke—Continued.

	Locality.	
	Standard coke, Connellsville.	St. Bernard, Kentucky.
Chemical analysis:		
Fixed carbon	87.46	86.94
Moisture	.49	----------
Ash	11.32	12.10
Sulphur	.69	1.96
Phosphorus	.029	.012
Volatile matter	.011	----------

Regarding these tests, Mr. Fulton writes: "From this table the very close resemblance of the physical structure of the St. Bernard coke to that of Connellsville will be observed. It is so nearly equal to it in cellular space and hardness that no distinction should be drawn. Its burden-bearing property slightly exceeds that of the Connellsville. This coke was made from washed slack. The sulphur is undoubtedly lower than would be found in ordinary practice." The No. 9 coal of western Kentucky usually carries about 2.50 per cent of sulphur. It would seem, therefore, that all that is needed to make the western Kentucky cokes strong competitors with Pennsylvania cokes is a successful process for reducing the amount of sulphur. The gradual increase in the output of western Kentucky coke indicates that to a certain extent it is meeting the competition successfully.

GAS-PRODUCING VALUE.

From the high percentage of volatile combustible matter in the coals of this field it might be supposed that they would be excellent gas producers. Outside of the cannel coal this does not appear to be the case. A study made in 1872 of the relative value of Indiana and Youghiogheny coals, the latter being taken as 100, gave as follows:

Gas-producing value of Indiana coals.

	Gas yield.	Illuminating power.	Coke.
Cannelburg (cannel), Daviess County, Ind	1.20	1.50	0.58
Standard shaft, Sullivan County, Ind	.90	.88	.90
Wilson shaft, Sullivan County, Ind	.98	.88	.97

The cannel coal of Cannelburg of course finds ready sale as an enricher, but largely on account of the poorer quality of the coke obtained in the process the other coals of the field are but little used for making illuminating gas. It is thought, however, that with the increased production and use of water gas and other power gases, where the coke obtained in the first part of the process is converted immediately into gas, these coals may be able to hold their own with other better known gas coals.

To summarize briefly the above statements relating to the coals of the Eastern Interior field: They have not as yet proved to be satisfactory for the manufacture of gas, except where they have great advantages in freights over Pennsylvania coals; the same is true of coke in Illinois and Indiana. On the other hand, the coke made from western Kentucky coal is of excellent quality, and is finding an ever increasing market. For steam production the coals of this field do not fall far behind the best eastern coals, and are superior to some of the latter, while they are probably as good as or better than most of the coals from the fields farther west.

DEVELOPMENT.

HISTORY OF DEVELOPMENT.

The main facts in the history of the development of the Eastern Interior coal fields can be shown in tabular form as follows:

1698.—First mention of coal in this field found by Father Hennepin on the Illinois River, near Fort Crève-Cœur. This is also the first mention of coal found in America.

1763.—Coal noticed on the Wabash River by Colonel Croghan.

1804.—Coal noted in land surveys in Indiana, and its position marked on the maps.

1811.—Coal dug at Fulton, Perry County, Ind., and taken aboard the steamboat *Orleans* by Robert Fulton, on its first trip down the Ohio River.

1830–1840.—Coal mined in a small way for shipment in all of the States of this field. Advertised for sale in Indiana in newspapers in 1832.

1837.—First coal company incorporated in Indiana, the American Cannel Coal Company, of Cannelton, Perry County, Ind.

1840–1850.—Considerable coal shipped down the Ohio from Union and Hancock counties, Ky., and from points along the Wabash, White and Ohio rivers in Indiana.

1850.—First coal shaft in Indiana sunk by John Hutchinson, near Newburg, Warrick County.

1851.—Indiana block coal discovered.

1852.—First shipments of Indiana block coal.

1850–1860.—Extensive mining of coal being carried on in Illinois, and started in Indiana. Kentucky still producing but a few thousand tons.

1867.—Over 1,500,000 tons of coal produced in Illinois.

1870.—Coal mining on extensive scale began in Kentucky.
Coal produced in Indiana, nearly 1,000,000 tons.
Coal produced in Illinois, over 2,500,000 tons.

1879.—Mining law passed in Indiana.
Illinois produces 4,000,000 tons of coal, third in rank in United States.
Indiana produces 1,500,000 tons of coal, fifth in rank in United States.
Kentucky produces 1,000,000 tons of coal, ninth in rank in United States.
1884.—Mining law passed in Kentucky.
1888.—Kentucky mining law amended to make effective.

The growth of production in this field since 1880 is shown by fig. 27.

METHODS OF MINING.

In Indiana the room-and-pillar method of mining is used exclusively. This varies in its details with different districts and different coal beds in the same district. Entrance is generally gained by a shaft, there being less than half a score of drifts and slope mines among the larger producers, though a large percentage of the small mines are either drifts or slopes. The shafts in Indiana range in depth from 50 feet or less to 440 feet. These are usually well equipped, many of them having self-dumping cages, shaking screens, etc. An average mine will have 6-foot entries, double entries always being used, an 18- to 24-foot pillar between entries, 12-foot pillar between entry and room, 8-foot pillar between rooms, and 24-foot rooms. There is usually one neck, turned at the center or more frequently at the side. Posts are set according to the demands of the roof, from one to the square yard to rooms 40 feet wide without a post. The variations from these figures may be considerable. Thus, rooms 30 and 40 feet wide are common, sometimes being worked with a double neck. Pillars vary in size up to 100 feet thick where necessary to guard against creep. In 1900, 32 out of 157 mines used mining machines and mined 1,875,986 tons out of 6,283,063 tons, or about 30 per cent. The number of mines employing mechanical haulage is rapidly increasing, rope haulage being used in those first equipped, and electric haulage in most of the later ones. Ventilation is entirely by downdraft steam fans.

In Illinois both room-and-pillar and long-wall methods are used, though the former largely predominates. In 1897, out of 853 mines in the State, only 52 used the long-wall method, and of these all but 10 were working coal No. 2 in the northeast portion of the State, where that bed is of good quality, but very thin, averaging not far from 3 feet. In this State, as in Indiana, shafts greatly predominate as the means of reaching the coal, only about a score of the larger mines being worked by slope or drift. In 1900, out of 323 shipping mines, 51 used mining machines, 430 machines being used, and 5,583,594 tons being machine mined out of a total of 25,153,929 tons, or about 25 per cent. The bulk of the machine mining has been in the central and southern part of the field. Until recently, mechanical haulage has been entirely by wire cable. Electric haulage is now being introduced to some extent. In the mines worked by the room-and-pillar system about one-half undercut the coal before blasting; the others blast the coal from the solid face.

In Kentucky, so far as learned, only the room-and-pillar method is used. A little less than half the mines in this district reach the coal by shafts, a majority of the remainder being drifts. The shafts, with one exception, are all under 200 feet in depth. Kentucky is a leader in the percentage of coal mined by machinery, having in 1900 24 mines in this district in which mining machines were used, the number of machines being 167 and the coal mined by them 1,835,219 tons, or 61 per cent of the total output of the district.

In Illinois and Indiana a large majority of the miners are white, the colored miners being mainly confined in Indiana to the southern part of the field. In both States such miners have in the main been brought in to take the place of strikers. In Kentucky a large proportion of the miners are colored. Of the white miners in Indiana and Kentucky, the figures at hand indicate that about one-half are foreigners. It seems probable that the proportion of foreign miners is on the increase. When mines are opened in new districts the miners at first are largely drawn from the surrounding farming region, and are of a high average of intelligence; but with the increase of mining operations at that point, professional miners drift in, a large percentage of whom are of foreign extraction and of a lower grade of intelligence.

The rates paid for mining vary in the different States and to a certain extent in the same State. As a rule, these rates are fixed by conference between organizations of miners and operators. In Illinois the price in 1900 ranged from 38 to 62 cents per ton for hand mining and from 31 to 43 cents for machine mining. The coal in this State by a recent agreement is nearly all paid for by the gross ton. Most payments are semimonthly.

In Indiana the rate by agreement is 49 cents a ton for run of mine and 80 cents for coal over standard screen. For machine-mined coal it is: Punching machine, run of mine, 39 cents; screened lump, 62 cents; chain machine, run of mine, 36½ cents; screened lump, 58½ cents. The prices given are for bituminous coal. The prices paid for mining the block coal run from 10 to 20 cents higher, according to the thickness of coal.

In Kentucky the agreed rate is 46½ cents a ton for run-of-mine coal and 75 cents for screened lump coal. Machine mining is paid for by the cut, $2.25 per 27 cuts, for chain machines. With the punch machines runners receive 28¼ cents and the helper 21¼ cents an hour.

DISTRIBUTION.

The Eastern Interior field supplies entirely or in part the fuel market for all of Indiana west and south of the Indiana gas field, all of Illinois, western Kentucky, western Tennessee, northwestern Alabama,

Counties
IN
ILLINOIS

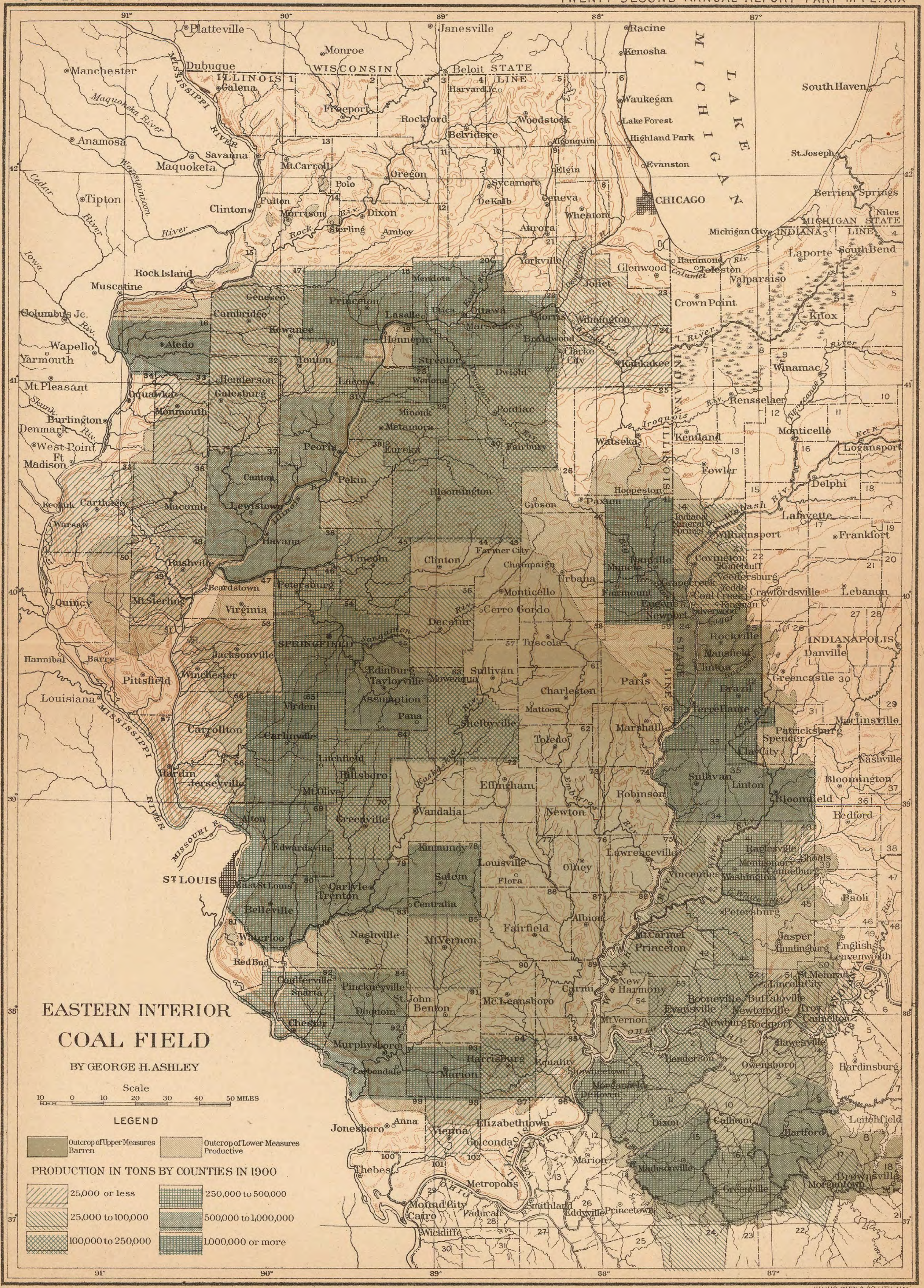
1 JO DAVIESS
2 STEPHENSON
3 WINNEBAGO
4 BOONE
5 MC HENRY
6 LAKE
7 COOK
8 DUPAGE
9 KANE
10 DEKALB
11 OGLE
12 LEE
13 CARROLL
14 WHITESIDE
15 ROCK ISLAND
16 MERCER
17 HENRY
18 BUREAU
19 PUTNAM
20 LASALLE
21 KENDALL
22 GRUNDY
23 WILL
24 KANKAKEE
25 IROQUOIS
26 FORD
27 LIVINGSTON
28 MARSHALL
29 WOODFORD
30 STARK
31 PEORIA
32 KNOX
33 WARREN
34 HENDERSON
35 HANCOCK
36 MC DONOUGH
37 FULTON
38 MASON
39 TAZEWELL
40 MC LEAN
41 VERMILION
42 CHAMPAIGN
43 PIATT
44 DEWITT
45 LOGAN
46 MENARD
47 CASS
48 SCHUYLER
49 BROWN
50 ADAMS
51 PIKE
52 SCOTT
53 MORGAN
54 SANGAMON
55 CHRISTIAN
56 MACON
57 MOULTRIE
58 DOUGLAS
59 EDGAR
60 CLARK
61 COLES
62 CUMBERLAND
63 SHELBY
64 MONTGOMERY
65 MACOUPIN
66 GREENE
67 CALHOUN
68 JERSEY
69 MADISON
70 BOND
71 FAYETTE
72 EFFINGHAM
73 JASPER
74 CRAWFORD
75 LAWRENCE
76 RICHLAND
77 CLAY
78 MARION
79 CLINTON
80 ST. CLAIR
81 MONROE
82 RANDOLPH
83 WASHINGTON
84 PERRY
85 JEFFERSON
86 WAYNE
87 EDWARDS
88 WABASH
89 WHITE
90 HAMILTON
91 FRANKLIN
92 JACKSON
93 WILLIAMSON
94 SALINE
95 GALLATINE
96 HARDIN
97 POPE
98 JOHNSON
99 UNION
100 ALEXANDER
101 PULASKI
102 MASSAC

INDIANA

1 LAKE
2 PORTER
3 LAPORTE
4 ST. JOSEPH
5 MARSHALL
6 STARKE
7 NEWTON
8 JASPER
9 PULASKI
10 FULTON
11 CASS
12 WHITE
13 BENTON
14 WARREN
15 TIPPECANOE
16 CARROLL
17 CLINTON
18 HOWARD
19 TIPTON
20 HAMILTON
21 BOONE
22 MONTGOMERY
23 FOUNTAIN
24 VERMILION
25 PARKE
26 PUTNAM
27 HENDRICKS
28 MARION
29 JOHNSON
30 MORGAN
31 OWEN
32 CLAY
33 VIGO
34 SULLIVAN
35 GREENE
36 MONROE
37 BROWN
38 JACKSON
39 LAWRENCE
40 MARTIN
41 DAVIESS
42 KNOX
43 GIBSON
44 PIKE
45 DUBOIS
46 ORANGE
47 WASHINGTON
48 HARRISON
49 CRAWFORD
50 PERRY
51 SPENCER
52 WARRICK
53 VANDERBURG
54 POSEY

KENTUCKY

1 UNION
2 HENDERSON
3 DAVIESS
4 HANCOCK
5 BRECKENRIDGE
6 MEADE
7 HARDIN
8 GRAYSON
9 OHIO
10 MC LEAN
11 WEBSTER
12 CRITTENDEN
13 LIVINGSTON
14 CALDWELL
15 HOPKINS
16 MUHLENBERG
17 BUTLER
18 EDMONSON
19 HART
20 BARREN
21 WARREN
22 LOGAN
23 TODD
24 CHRISTIAN
25 TRIGG
26 LYON
27 MARSHALL
28 MC CRACKEN
29 BALLARD
30 CARLISLE
31 GRAVES



JULIUS BIEN & CO. LITH. N.Y.

Mississippi, points in Louisiana and Arkansas on the Mississippi River and its tributaries, eastern Missouri, eastern Iowa and portions of eastern Nebraska, Minnesota, the Dakotas, and Wisconsin.

Its coal comes in competition over the whole of this area with anthracite from Pennsylvania, mainly for household purposes; also with bituminous coal from Pennsylvania shipped by water to Chicago. During the summer months, while lake navigation is open, the Pennsylvania bituminous coal about kills the trade of this field for Chicago and the surrounding region, as well as that bordering the lakes to the west and northwest. Hence the Chicago trade is confined chiefly to the winter months. The heavier demand while lake navigation is closed somewhat compensates for the shortness of the season.

Most of northern Indiana, at present an important manufacturing center; a part of Chicago, Louisville, and other points along the eastern margin of the field are now supplied with cheap natural gas. This, however, is rapidly nearing exhaustion, and its place is being taken in part by coal from this field. The demand from this quarter is bound to increase rapidly, its effects already being visible in the increased demand for and output of Indiana coal. The northeastern portion of the field receives the greatest benefit by this enlarging of the market due to the diminution in supply of natural gas.

The Eastern Interior field also competes with the Appalachian field at points supplied by rail. This factor determines the eastward extension of the market area. It becomes a question of higher freight charges on a smaller amount of fuel as against lower freight on more fuel to obtain a given amount of power. The eastern coals being usually the better, the line separating the two market areas runs nearer the Interior than the Eastern field. It competes with Pittsburg and Kanawha coals at points reached by Ohio River transportation. The better coal from the Appalachian field practically controls the market along the Ohio and the Mississippi rivers, except for screenings for steam purposes. This field, however, is called on to supply the territory along these rivers when conditions prevent river shipments from above.

In middle and western Tennessee and northern Alabama and Mississippi the field comes in competition with the Tennessee and Alabama fields, the control of the market at any particular point depending on the freight rates from the various fields and the quality of fuel required. Competition with the Western Interior coal field limits the market on the west and southwest. Here the competition is with an inferior fuel, and hence the line between the market areas of the two fields is nearer the Western than the Eastern field. Internal competition occurs between the Indiana block coal and the other coals of the field. The block coal is more expensive to mine, and its greater cost, therefore, offsets in some measure the advantage which it possesses due to its better quality. Certain differences in quality allow in some cases successful competition between coals at different distances from the point of consumption. Thus, coals shipped from Kentucky successfully compete in Evansville, Ind., with coal mined in Evansville. Much of the internal competition in the field means simply a diminution in profits to those placed at a disadvantage. Thus, all parts of the field ship to Chicago, St. Louis, and other points where there is a large market, although with very different rates of profit.

PROPORTIONAL CONSUMPTION OF PRODUCT.

It is impossible to give accurate figures of the proportional consumption, first, because many of the largest producers failed to give full returns; second, because it is difficult to follow the final disposal of coal shipped to local dealers. The following estimates, based on inquiries from this Survey, are, therefore, only approximate:

Production and distribution of product of the Eastern Interior coal field for 1900.

Subdivision of field.	Production.	Value at mines.	Average value per ton.	Railroad fuel.	
				Quantity.	Per cent.
	Short tons.			*Short tons.*	
Indiana	6,484,086	$6,687,137	$1.03	1,943,663	29.98
Block coal	1,169,329	1,604,404	1.38		
Bituminous	5,314,757	5,082,733	.96		
Illinois	25,767,981	26,927,185	1.04	7,988,074	31
Kentucky (west)	3,096,097	2,578,912	.83	1,265,654	41
Total for field	35,348,164	36,193,234	1.02	11,197,391	31.7

Subdivision of field.	Steamboat fuel.		Manufacturing fuel.		Domestic fuel.		Made into coke.	
	Quantity.	Per cent.	Quantity.	Per cent.	Quantity.	Per cent.	Quantity.	Per cent.
	Short tons.		*Short tons.*		*Short tons.*		*Short tons.*	
Indiana			2,073,240	31.97	2,461,973	37.97		
Block coal								
Bituminous							2,605	.04
Illinois	515,360	2	9,018,793	35	8,245,754	32		
Kentucky (west)			994,442	32	753,366	24	82,635	3
Total for field	515,360	1.5	12,086,475	34.2	11,461,093	32.4	85,240	.02

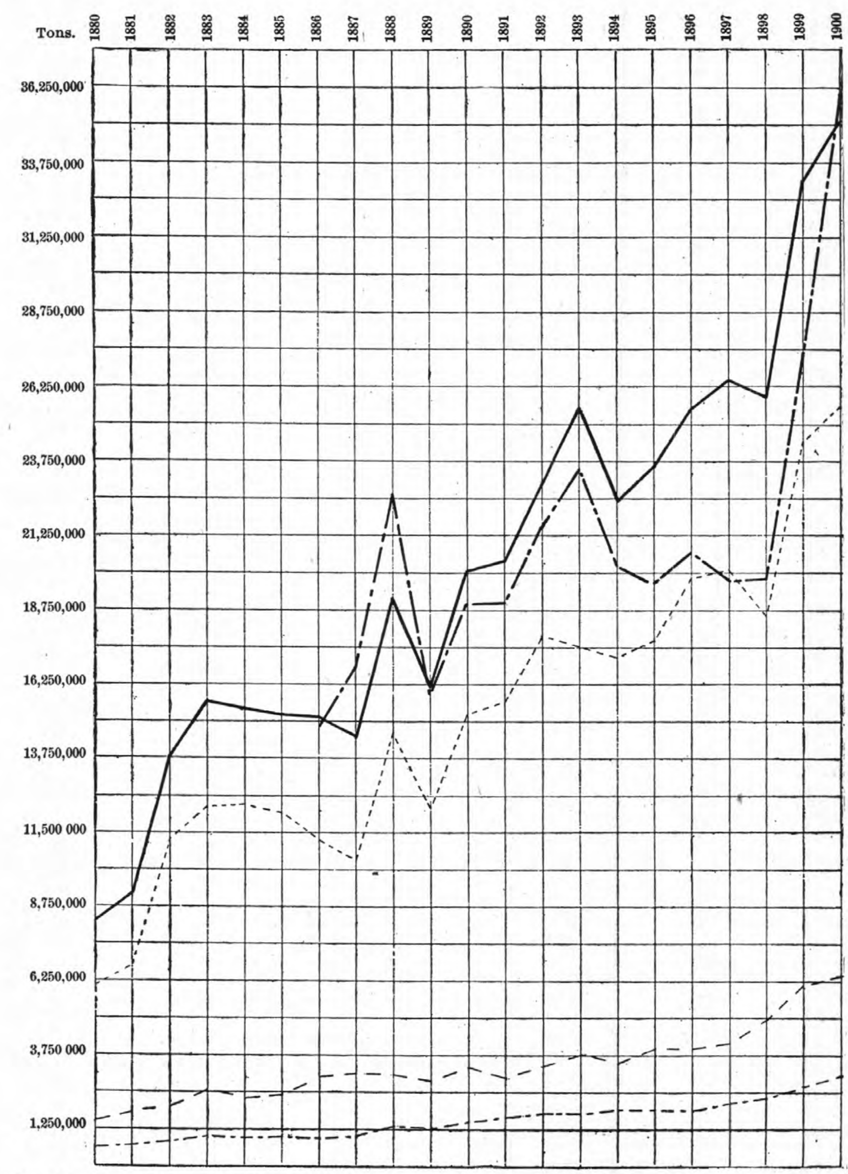


FIG. 27.—Production and value of coal in Eastern Interior field, including Illinois, Indiana, and western Kentucky, from 1880 to 1900.

------- Illinois. ——————— Indiana. —-—-—-— Western Kentucky. ———— Total production. ▬ ▬ ▬ Total value.

Scale { 1,250,000 tons to the square.
$1,250,000 to the square.

So far as could be learned, only one mine is at present exporting coal. That is the Wheatcroft mine, in Webster County, Kentucky, which is making shipments to Mexico via New Orleans.

In the reports of the mine inspectors of Illinois for 1900 the following disposition of the coal is given for that State:

Disposition of coal in Illinois.

	Tons.
Shipped	21,009,803
Supplied to locomotives	821,937
Supplied to local trade	1,231,652
Consumed or wasted at mines	993,604

It is probable that these figures do not include under the head of "Supplied to locomotives" the coal shipped from the mines to be used on distant parts of the road or on other roads. On the other hand, it is probable that a large part of the coal reported to this Survey as "supplied to railroads for fuel" was simply supplied for fuel purposes, though not necessarily for railroad use. In like manner, many of the operators in making returns of coal supplied for "local household trade" included coal shipped for household use as well as that used locally.

PRESENT ROUTES TO POINTS OF CONSUMPTION.

In the three States concerned, nearly the whole product is shipped by rail. According to the Illinois mine inspectors' reports for 1900, the following roads in that State carried over 500,000 tons:

Railroads in Illinois carrying more than 500,000 tons.

	Tons.
1. Illinois Central	5,322,456
2. Chicago, Burlington and Quincy	1,799,695
3. Chicago and Eastern Illinois	1,789,965
4. Wabash	1,586,073
5. Chicago and Alton	1,365,975
6. Chicago, Peoria and St. Louis	1,292,870
7. Baltimore and Ohio Southwestern	1,114,007
8. Elgin, Joliet and Eastern	979,270
9. Cleveland, Cincinnati, Chicago and St. Louis	737,456
10. Chicago and Northwestern	726,040
11. Southern Louisville, Evansville and St. Louis Consolidated	573,733
12. Atchison, Topeka and Santa Fe	572,681
13. Chicago, Rock Island and Pacific	564,744
14. Louisville and Nashville	540,507
15. Terre Haute and Indianapolis	503,527

According to the same report, 13,000 tons were shipped by the Rock River and 3,000 tons by the Illinois River. In all, thirty-three roads share in the transportation of the Illinois coal product.

In Indiana the principal coal haulers among the railroads with the markets to which the coal is hauled are: Chicago and Eastern Illinois to Chicago; Indianapolis and Terre Haute to Indianapolis; Big Four to Indianapolis; the Vandalia Line to the northeast; the Evansville and Terre Haute to connecting roads at Terre Haute for Chicago and

Indianapolis; the Evansville and Indianapolis to Evansville and connecting roads; the Indianapolis and Vincennes to Indianapolis; the Baltimore and Ohio Southwestern to St. Louis and points east of field; the Indiana Southern to points in south central Indiana; the Southern (Louisville, Evansville and St. Louis Consolidated) to St. Louis and Louisville.

In Kentucky the railroads operating in the western field and the amount of coal mined along each in 1900, from the State report for that year, are as follows:

Railroads operating in Kentucky coal field.

	Tons.
Louisville and Nashville	1,534,192
Illinois Central	1,293,340
Louisville, Henderson and St. Louis	81,160

A small amount of coal is shipped from these States by boat. In Illinois these shipments are made mainly by rail to the Mississippi and Ohio rivers and then southward by boat. In Indiana such shipments are confined to Evansville, Newburg, Troy, and Cannelton on the Ohio River. In Kentucky the coal of Butler County is shipped down Green River, and some other shipments are made from points along the Ohio.

CAPACITY OF PRESENT FACILITIES.

As full returns are at hand from only a small proportion of the mines of this field, conclusions must be based on percentages. In the following table are given the number of mines in each district, their total production in 1900, their estimated total capacity, the ratio of output to capacity, and the percentage of mines reporting prospective increase in capacity:

Relation of production to capacity of mines for the Eastern Interior coal field in 1900.

State.	Number of counties producing coal.	Number of commercial mines.	Production, 1900.	Estimated capacity of mines.	Ratio of production to capacity.	Per cent of mines reporting prospective increase of capacity.
			Short tons.	*Short tons.*		
Indiana	16	164	6,484,086	8,795,287	74	50
Illinois	48	523	25,767,981	62,722,819	41	39
Kentucky (west)	11	53	3,096,097	3,591,677	86	85
Total	87	799	35,348,164			

From these reports it is evident that the prospects for enlargement are excellent all over the field. In Indiana, in 1900, about 30 new mines were opened, nearly all on a large scale and well equipped with electric mining machinery, and a number of the old mines were equipped with mining machinery; and as only two mines were abandoned during the year, it is estimated that the producing capacity of the State was increased about one-fourth.[a]

In conclusion, it is seen that this field not only has coal enough to supply the present or prospective demand for many generations, but that with the present and constantly increasing facilities the field is prepared to meet a much larger demand.

TRANSPORTATION CHARGES.

The following table gives a summary of the rates from some of the coal counties to some of the principal cities to which shipments are made:[b]

Freight rates between principal coal counties of Eastern Interior field and important cities.

	Chester, Ill.	Chicago, Ill.	Dubuque, Iowa.	East St. Louis, Ill.	Fort Madison, Iowa.	Joliet, Ill.	Madison, Wis.
ILLINOIS.	*Dollars.*	*Dollars.*	*Dollars.*	*Dollars.*	*Dollars.*	*Dollars.*	*Dollars.*
Christian County	....	0.75	1.38	....	....	....	1.67
Jackson County	....	....	....	0.52½	....	....	....
Lasalle County	....	.50 to .55	....	....	....	0.50	....
Madison County	....	....	....	.35	....	....	....
Marshall County	....	.50	....	....	0.75	....	....
Perry County	0.40	.90	....	.42½	....	....	....
Randolph County	....	....	....	.35	....	....	....
Sangamon County	....	.75 to 1.00	....	....	....	....	....
St. Clair County	....	....	....	.35	....	....	....
Will County	....	.50	....	....	....	.50	....
Williamson County	....	.95	....	.37½	....	....	....
INDIANA.							
Clay County	....	.70	....	....	....	....	....
Gibson County	....	1.15	....	.60	....	....	....
Greene County	....	.80	....	....	....	....	....
Pike County	....	1.15	....	.60	....	....	....
Sullivan County	....	.80	....	....	....	....	....
Parke County	....	.70	....	....	....	....	....
Vanderburg County	....	....	....	....	....	....	....
Vermilion County	....	.70	....	....	....	....	....
Vigo County	....	.70	....	....	....	....	....
Warrick County	....	....	....	....	....	....	....
KENTUCKY.							
Union County	....	....	....	....	....	....	....
Webster County	....	....	....	....	....	....	....

[a] Letter of Mr. Epperson of May 24.

[b] Bridge toll to St. Louis is 30 cents.

Freight rates between principal coal counties of Eastern Interior field and important cities—Continued.

	Memphis, Tenn.	Nashville, Tenn.	Omaha, Nebr.	Peoria, Ill.	Sioux City, Nebr.	St. Louis, Mo.	St. Paul, Minn.
ILLINOIS.	*Dollars.*	*Dollars.*	*Dollars.*	*Dollars.*	*Dollars.*	*Dollars.*	*Dollars.*
Christian County	....	....	....	....	....	....	....
Jackson County	....	....	....	....	....	0.82½	....
Lasalle County	....	....	2.00	....	2.41	....	1.65
Madison County	....	....	....	....	....	.65	....
Marshall County	....	....	....	....	....	....	....
Perry County	....	....	2.22½	....	....	.72½	....
Randolph County	....	....	....	....	....	.65	....
Sangamon County	....	....	....	0.45	....	....	....
St. Clair County	....	....	....	....	....	.65	....
Will County	....	....	....	....	....	....	....
Williamson County	1.20	1.50	2.37½	....	....	.67½	2.20
INDIANA.							
Clay County	....	....	....	....	....	....	....
Gibson County	....	....	....	....	....	.90	....
Greene County	....	....	....	....	....	....	....
Pike County	....	....	....	....	....	....	....
Sullivan County	....	....	....	....	....	....	....
Parke County	....	....	....	....	....	....	....
Vanderburg County	....	....	....	....	....	.90	....
Vermilion County	....	....	....	....	....	....	....
Vigo County	....	....	....	....	....	....	....
Warrick County	....	....	....	....	....	....	....
KENTUCKY.							
Union County	1.25	1.00	....	....	....	....	....
Webster County	1.25	....	....	....	....	....	....

Freight rates between principal coal counties of Eastern Interior field and important cities—Continued.

	Clarksville, Tenn.	New Orleans, La.	Indianapolis, Ind.	Louisville, Ky.	New Albany, Ind.	Terre Haute, Ind.	Elwood, Ind.
ILLINOIS.	*Dollars.*	*Dollars.*	*Dollars.*	*Dollars.*	*Dollars.*	*Dollars.*	*Dollars.*
Christian County							
Jackson County							
Lasalle County							
Madison County							
Marshall County							
Perry County							
Randolph County							
Sangamon County							
St. Clair County							
Will County							
Williamson County		1.75					
INDIANA.							
Clay County			0.50 to .60			0.35	0.70
Gibson County			1.05	0.60	0.60		
Greene County			.50				.70
Pike County			1.05	.60	.60		
Sullivan County			.45 to .50			.30	
Parke County			.50				.70
Vanderburg County				.60	.60		
Vermilion County			.50				
Vigo County							
Warrick County				.60	.60		
KENTUCKY.							
Union County	1.25						
Webster County		1.25					

Local rates or rates to the smaller towns are, of course, proportionally higher. Thus, from Streator to Chicago, 94 miles, is 50 cents; from Streator to Wedron, 27 miles, is 60 cents. Omaha, Sioux City, and St. Paul are each 500 miles from Lasalle County, but the rates vary from $1.65 to $2.41. From Union County, Ky., to Clarksville, Tenn., is 70 miles, to Memphis is 325 miles, yet the rate differs by only 5 cents.

LITERATURE.

On account of the general and condensed nature of the body of this paper but few references are given in the text. A short summary of the more important reports bearing on this coal field is given here. No reference is made here to works on coal or the coal fields in general.

1838.—D. D. Owen, Geological Reconnaissance of Indiana.

1844.—D. D. Owen, Geological Exploration of parts of Iowa, Wisconsin, and Illinois.
Contains chart of the great Illinois coal field.

1843.—James Hall, Geology of New York, Part IV.
Gives geological map of Middle and Western States. Also section from Cleveland, Ohio, to Mississippi River, in a southwest direction.

1848.—R. C. Taylor, Statistics of Coal.
Contains map of this field.

1848.—David Christy, Letters on Geology.
Describes structure of field.

1853.—R. T. Brown, Geological Survey of Indiana.

1862.—Richard Owen, Geological Reconnaissance of Indiana.

1866.—A. H. Worthen, Geological Survey of Illinois, Vols. I to VIII (1890).
Vol. I, devoted entirely to geology.
Vol. II, paleontology.
Vols. III to VI, inclusive, have the first half or a little less given up to geology.
Vols. VII and VIII contain each a brief summary of recently obtained well sections, etc.

1870.—E. T. Cox and others, Geological Survey of Indiana, vols. 1 to 25.
Of the earlier reports vols. 1, 2, 3, and 4, 5, 6, 7, 8–10, and 11 contain reports of the coal counties. Vol. 23, in 1,573 pages, attempts to give a summary of all previously published data on the Indiana part of the field, besides the results of an entire resurvey of the field, with maps, on scale of 2 miles to the inch.

1879.—Reports: Mine Inspectors of Indiana.
Mine Inspector of Illinois.

1884.—Reports Mine Inspectors of Kentucky.
Mine inspector's reports of the three States contain very full statistics of the mining and much data on the coal and geology.

1895.—Final Report of Illinois Board of World's Fair Commissioners.

1898.—Frank Leverett, Seventeenth Annual Report U. S. Geological Survey, Part II.

1899.—Frank Leverett, Monograph XXXVIII, U. S. Geological Survey.
This and the last have map of coal field and many notes of value.

1900.—Marius R. Campbell, Geological Atlas of United States, folio 67.
Treats in detail the region around Danville, Ill.

THE NORTHERN INTERIOR COAL FIELD

BY

ALFRED C. LANE

CONTENTS.

ILLUSTRATIONS.

THE NORTHERN INTERIOR COAL FIELD.

By Alfred C. Lane.

GEOGRAPHIC RELATIONS.

LOCATION AND BOUNDARIES.

The Michigan coal field lies in the center of the Lower Peninsula of Michigan, between Lake Michigan and Lake Huron, and extends from Jackson County on the south to Roscommon County on the north and from Tuscola County on the east to Kent County on the west. It embraces an area of approximately 7,500 square miles. It is the only coal field known in the drainage basin of the St. Lawrence. Lake Huron is connected with the center by Saginaw Bay and the estuary known as Saginaw River, which separate the Thumb of Lower Michigan from the main peninsula.

For the most part the coal basin is a low, flat country, in which the streams have cut but shallow valleys, and rarely exposed bed rock. It is surrounded by a rim of higher land, which rises from 1,000 to 1,500 feet above the sea, or 400 to 1,000 feet above lake level. This bounding rim of higher land is produced primarily by heavy sandstones and limestone of the Eocarboniferous—St. Louis or Maxville and Marshall groups—which lie under the coal. The contrast between the basin and the high land surrounding it has been accentuated by the heavier deposits of surface materials left by the ice of the Glacial epoch, which were also heaped up on the higher parts of the rock surface. The whole basin has been covered by such surface deposits and by lake deposits, so that the original minor topographic features have been practically obliterated.

SUBDIVISIONS OF THE FIELD.

Any subdivisions that may be made will be to a large extent artificial, and will really represent the spread of development from the different centers of exploitation, which usually owe their beginning to the accidental discovery of coal. In their historical order they will be taken as follows:

1. The Jackson field, dating back to 1835, includes the mines around Jackson, of which the New Hope has been the most prosperous for the last few years. The Jackson Coal Company ran a shaft for a few

months in 1900. The Eureka and Trumbull have been worked until recently, and there are a number of older shafts abandoned and some new ones projected.

2. The Cedar Grand field includes various small coal banks around Grand Ledge and the coal which has been found at one time and another around Williamston. All the work done in this region has been in an area 20 miles each way from Lansing. The work has been mainly in Eaton and Ingham counties.

3. The Owosso district includes all the mines which have been opened in the neighborhood of Owosso and Corunna. Within this same district may be included the little coal that has been obtained near Flushing and Elk, Genesee County, as well as Shiawassee.

4. The Saginaw district includes Saginaw County, the mines developed around Saginaw and St. Charles, and also the Verne mine which might, however, better be attached to the Owosso district.

5. The Bay field includes the counties bordering on Saginaw Bay—Arenac, Tuscola, and Bay counties, and the Sebewaing field of Huron County.

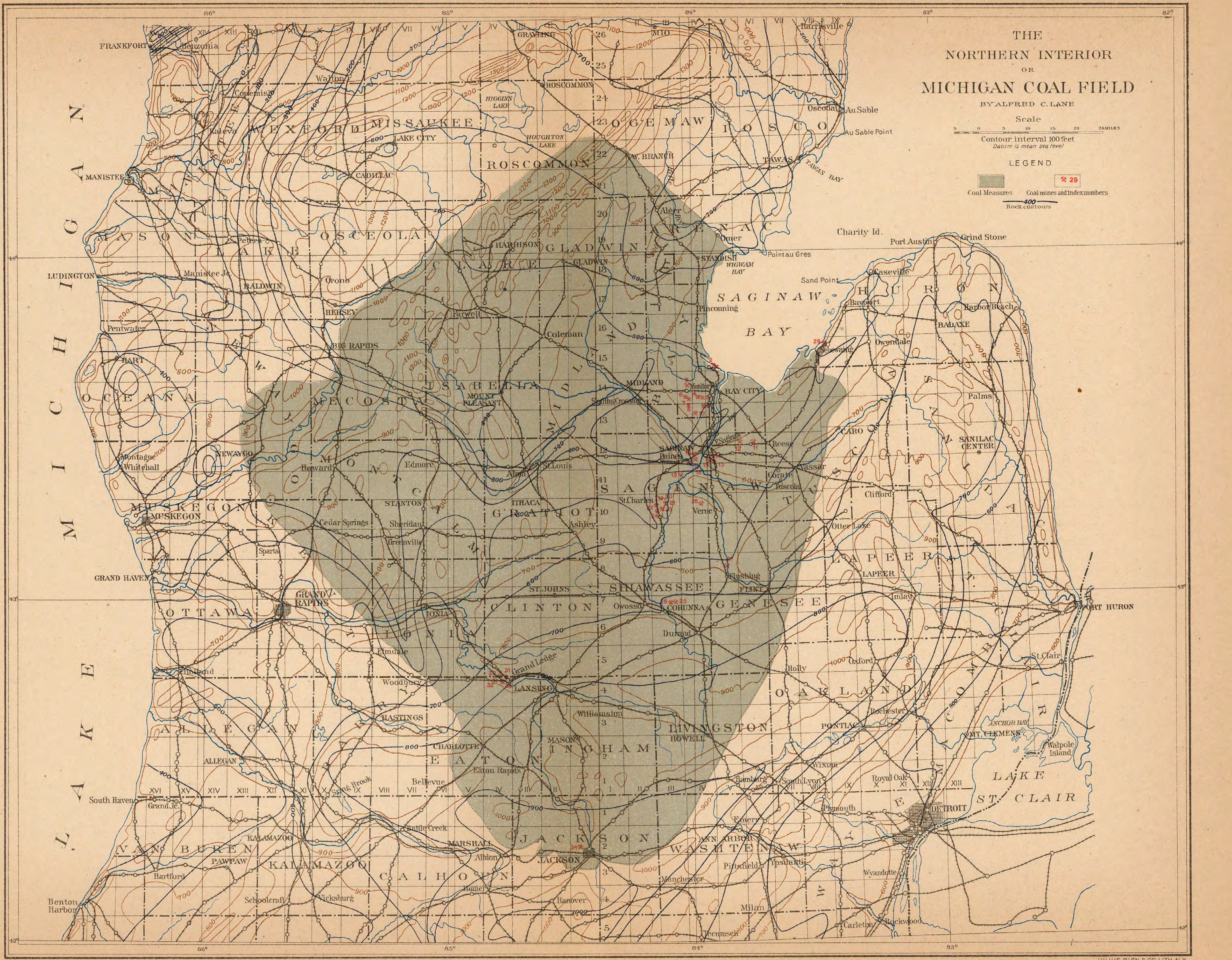
The order here given is very nearly that of their exploitation, except that the Sebewaing field is older in point of development than the Saginaw district. Although these subdivisions are not wholly artificial, since they correspond to certain peculiarities of the coal, their boundaries are arbitrary and must be so in the present state of our knowledge.

PROBABLE EXTENSION.

Owing to the thick coating of drift, the prospecting has been almost entirely by churn drill, either by holes drilled purposely for coal or by those drilled for water. Large portions of the area yield flowing wells when properly drilled. In fact, it is quite likely that flowing wells could have been obtained in the lower portion of any township in the coal basin before the tax upon the water resources became so great as it is at present. Since deep wells are naturally resorted to wherever the surface water supply is not satisfactory, it may be safely predicted that new areas of coal will be found in the process of well drilling and that these areas will be further extended by special explorations. Some indication as to the extent of the coal basin is afforded by the amount of coal in the glacial drift and the probable direction from which it came. On the accompanying map the basin has been extended to include all the country which is likely to contain coal, though in a few cases the coal seams may extend beyond its limits as there represented. A word of warning may not be out of place. The reports of coal near Detroit, New Baltimore, Alpena, and west toward Charlevoix, are usually due to the presence of Devonian black shales, and this region may safely be assumed to be without commercial coal.

LIST OF COAL OPERATORS

1	HANDY BROS. MINING CO.	BAY CITY
2	WENONA COAL MINING CO.	" "
3	WOLVERINE COAL CO.	WEST BAY CITY
4	MICH. COAL AND MINING CO.	BAY CITY
5	CENTRAL COAL MINING CO.	" "
6	MONITOR COAL CO.	" "
7	BAY COAL MINING CO.	" "
8	" " " "	" "
9	VALLEY COAL CO.	WEST BAY CITY
10	PITTSBURG COAL CO.	" " "
11	IMPERIAL COAL CO.	SAGINAW
12	BARNARD & CO.	"
13	PERE MARQUETTE COAL CO.	"
14	SAGINAW COAL CO.	"
15	STANDARD MINING CO.	"
16	PERE MARQUETTE COAL CO.	"
17	CHAPPELL & FORDNEY	"
18	RIVERSIDE COAL CO.	"
19	NORTHERN COAL AND TRANSPORTATION CO.	"
20	J.H. SOMERS COAL CO.	ST. CHARLES
21	ROBERT GAGE COAL CO.	" "
22	MICHIGAN COAL CO.	" "
23	J.H. SOMERS COAL CO.	" "
24	ST. CHARLES COAL CO.	" "
25	CORUNNA COAL CO.	CORUNNA
26	OWOSSO COAL CO.	OWOSSO
27	SAGINAW CLAY MFG. CO. MINING DISCONTINUED	SAGINAW
28	VERNE COAL CO. MINING DISCONTINUED	"
29	MICH. STANDARD COAL CO.	SEBEWAING
	SEBEWAING COAL CO.	"
	SAGINAW BAY COAL CO	"
30	FARGO BOYLE	GRAND LEDGE
31	R.W. PRATT	"
32	GEO. W. ARNOLD	"
33	R. WILKESON	"
34	NEW HOPE COAL MINING CO.	JACKSON



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GEOLOGIC RELATIONS.

AGE OF COAL-BEARING ROCKS.

It would not be unnatural to assume that the coal-bearing rocks were far down in the coal-bearing series, but as they are separated by unconformities from the beds below, this could not be readily determined. Recent discoveries indicate that the Michigan Coal Measures are equivalent to the Pottsville formation. This was formerly supposed to be below the Coal Measures, though it is now known that the Lykens Valley coal of Pennsylvania and important West Virginia and Tennessee coals are of this age. The Verne coals, near the top of the section, seem to correspond with the Mercer coals of Ohio. In the center of the basin there are 600 or 700 feet of Coal Measures.

Usually just above the coal is a black shale. Sometimes the coal passes into an impure cannel or bone coal (see analysis 3, p. 322), which has a conchoidal fracture and a large amount of ash. The presence of these low grades of cannel is rather characteristic of the Michigan field as a whole, and all the reports of 7 feet or more of coal have proved to refer to material of this character. The black shale usually passes upward into a dark-blue shale in which are frequently thin bands and nodules of carbonate of iron. These often contain sulphides of zinc and iron and sometimes kaolinite in the center. Beneath the coal there is usually a white shale known to the drillers as fire clay. It is scarcely refractory enough, however, for real fire clay.[a] Not infrequently it passes into sandstone. Occasionally in connection with the Verne coal there is a dark bituminous shaly limestone. Here and there in the coal series are large beds of white sandstone, and in some cases toward the top a red or variegated sandstone, but this red color may be due to alteration. The sandstones, however, do not appear at any constant point in the series, but may replace the ordinary beds at almost any point, very much as the sandy "oak island" rises from and replaces the muck marshes along the shores of Saginaw Bay. The relations of the sandstones to the coal, as seen in the mines, resemble those of sand dunes to marshes in their bottoms. The series given, viz, white shale or sandy fire clay, coal, cannel coal or black shale, and blue shale with nodules or limestones, is repeated in the case of seven or more different seams.

The base of the coal series is frequently a sandstone, which Winchell called the Parma sandstone, though this is sometimes absent.

Toward the middle of the basin the limestones which underlie the coal and outcrop near Bayport, Jackson, Grand Rapids, and Omer occur at increasing depths, until in the Midland well they are 920 feet below the surface and over 300 feet below tide level (fig. 31), while at

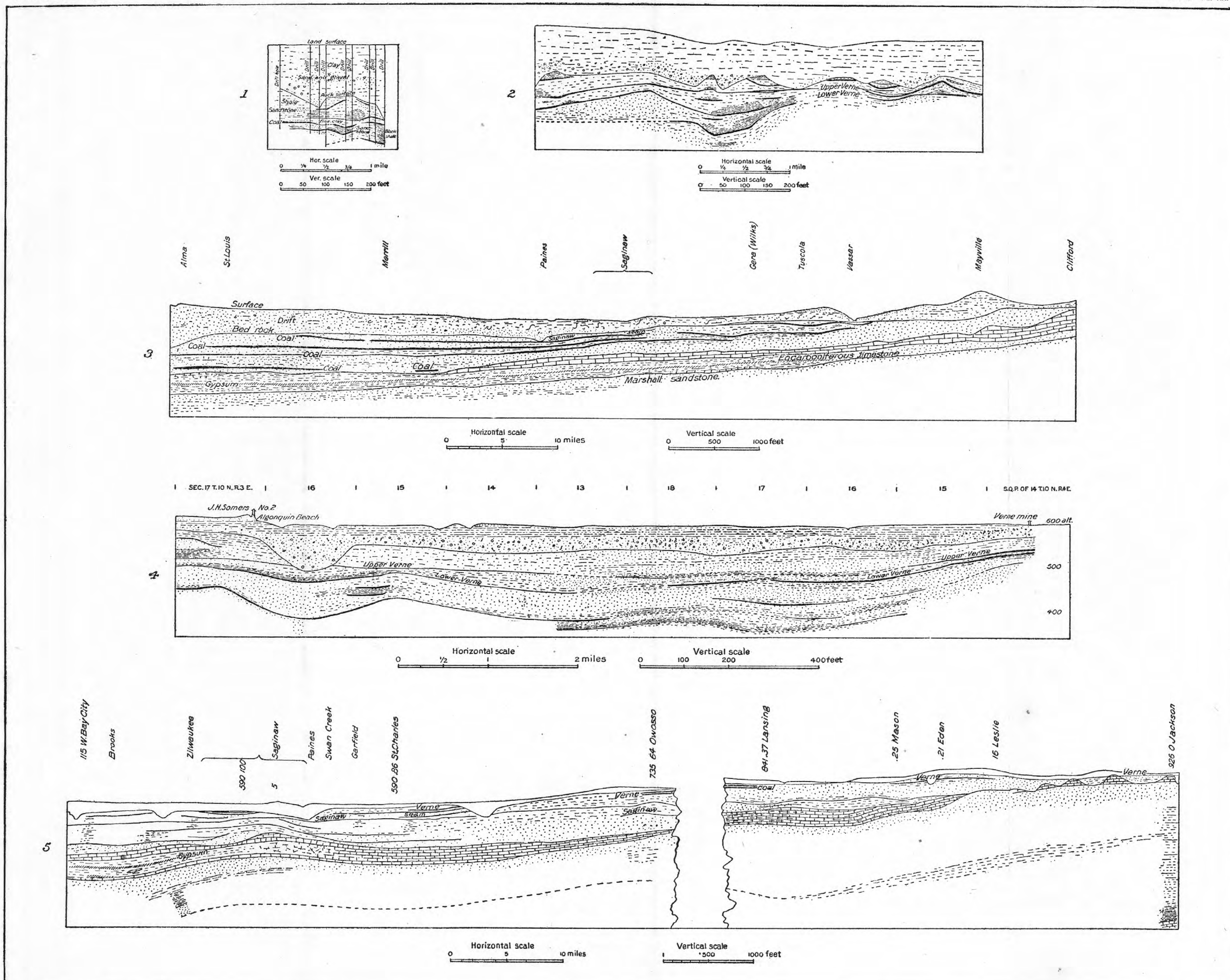
[a] See Report by H. Riés, Geological Survey of Michigan, Vol. VIII, Pt. I.

Sebewaing they are not more than 100 feet in depth and at Saginaw about 400 feet. This indicates a dip of about 10 feet per mile, but in following the coal seams no such general dip toward the center of the basin is found. The Verne coals may be followed from around Bay City with no great gaps toward the Wolverine mine and probably to Smiths Crossing; they seem to remain at practically the same level. There is some reason to believe that the Bay City, Sebewaing, and Verne coals are from the same bed, which has a very slight dip. The general conclusion at present from a study of the records, as shown by Pl. XXI, is that there is practically no general dip in the upper coal seams, but only minor undulations, which seem partly at least due to irregularity of deposition. If this is the case it follows that the lower part of the coal series is not found at the margin of the field, and that during a period in which the Eocarboniferous strata were raised and eroded they were also compressed into the form of a shallow basin, which as it sank again was filled by beds which are still practically horizontal. This is the general theory toward which the facts represented on Pl. XXI will lead, and it does not seem an unnatural one. The indications of unconformity at the sides of the basin would imply that while erosion was taking place here, deposits might be formed toward the center. The fact that the coal is found at considerable depth, at any rate from St. Charles to Bay City, and also at Alma, would imply that the water line was at one time at about that point. As the basin sank, coal might have been formed at some points about the margin all the time, and occasionally have spread farther out toward its center, so that the coal beds might actually make zigzags through the stratigraphic column. As a matter of fact, this is what they seem to do.

If this is so, it is easy to see also that the coal beds of the margin would correspond to the upper coals of the middle, and this appears also to be true so far as their chemical character is concerned. For instance, the Jackson, Sebewaing, and Verne coals are coking coals, while the only coal derived from a greater depth than these, the Saginaw, is not a coking coal. One reason for classing the two coal seams at Bay City, at present the only ones worked at that place, with the Verne and other coals, is that they are all coking coals. It is also true that these coals are much farther above the base of the Coal Measures than the Saginaw seam at West Saginaw and St. Charles.

STRUCTURE OF THE FIELD.

The structure of the field is a very flat, gentle synclinorium, whose longest diameter is perhaps from northeast to southwest. This is modified by minor undulations, such as are shown in fig. 28 and Pl. XXI. In the Sebewaing coal mine (fig. 28) there is a distinct fault,



SECTIONS OF MICHIGAN COAL FORMATIONS.

1, Section from SW. 1/4 of SE. 1/4 of sec. 15, T. 13 N., R. 4 E., in a direction N. 37° W., Bay County; 2, section from the Amelith shaft, N. 30° E., to the Central and Michigan mines, Bay County; 3, section on line of Pere Marquette Railway from Alma eastward through Saginaw to Clifford; 4, section from Somers No. 2 shaft, S. 80° E., to the Verne mine, near Verne station, Saginaw County; 5, section on the line of the Michigan Central Railway from Bay City southward to Jackson.

near which the coal has a decided dip, but in general, so far as investigation has gone, disturbances of that kind are very infrequent and slight compared with those of many other fields. Previous to the Ice age the field was subjected to erosion and was elevated much higher above base-level than at present. The rock surface had channels cut in it (see Pl. XXI) certainly more than 200 feet in depth by streams which

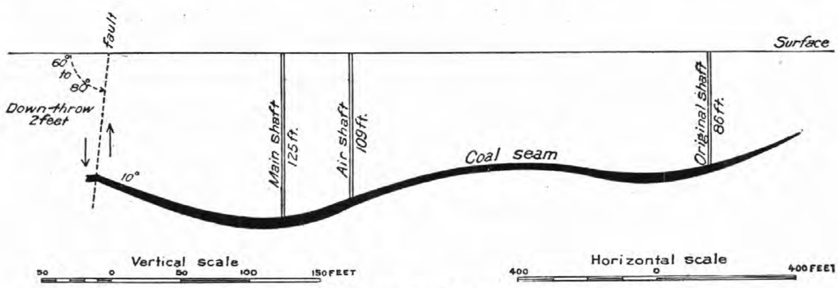


FIG. 28.—Cross section of Sebewaing shaft.

apparently drained to the west and northwest. These pre-Glacial drift-filled channels or washouts cause very great uncertainty in mining.

The present streams have rarely cut through the thick mantle of drift, and hence little or no coal has been lost by post-Glacial erosion. Just how much has been lost by pre-Glacial erosion can not be at present determined.

THE COAL.

NUMBER AND EXTENT OF WORKABLE BEDS.

It was formerly supposed that there was but one workable coal bed in Michigan, but recent investigations have demonstrated that this is not the case. Seven horizons are at present known at which occur coal beds that are in places workable. Of these, three are probably much more important than the others. Owing, however, to the varying character of the formation and to the way coal beds come together and separate, it is plain that no hard and fast classification can be made, and the following scheme seems sufficient for the present: Upper Rider, Upper Verne, Lower Verne, Middle Rider, Saginaw Coal, Lower Rider, Lower Coal. Taking these in their order, the Upper Rider is probably a split from the Upper Verne. The Upper and Lower Verne usually come close together and are mined together in the Wenona and Handy Brothers mines. The Michigan Coal and Mining Company formerly mined the lower, but have changed to the upper. The Monitor and Bay mines are probably working upon the upper seam, and the Pittsburg Amelith shaft is on the lower. The Grand Ledge, Sebewaing, Owosso, and Jackson workings are at about this horizon.

The quality of the Upper Verne appears to be generally the better of the two. It is duller, but has less sulphur. These two seams are thus seen to have considerable extent, although their thickness varies from place to place. The thickness of a single bed is not generally

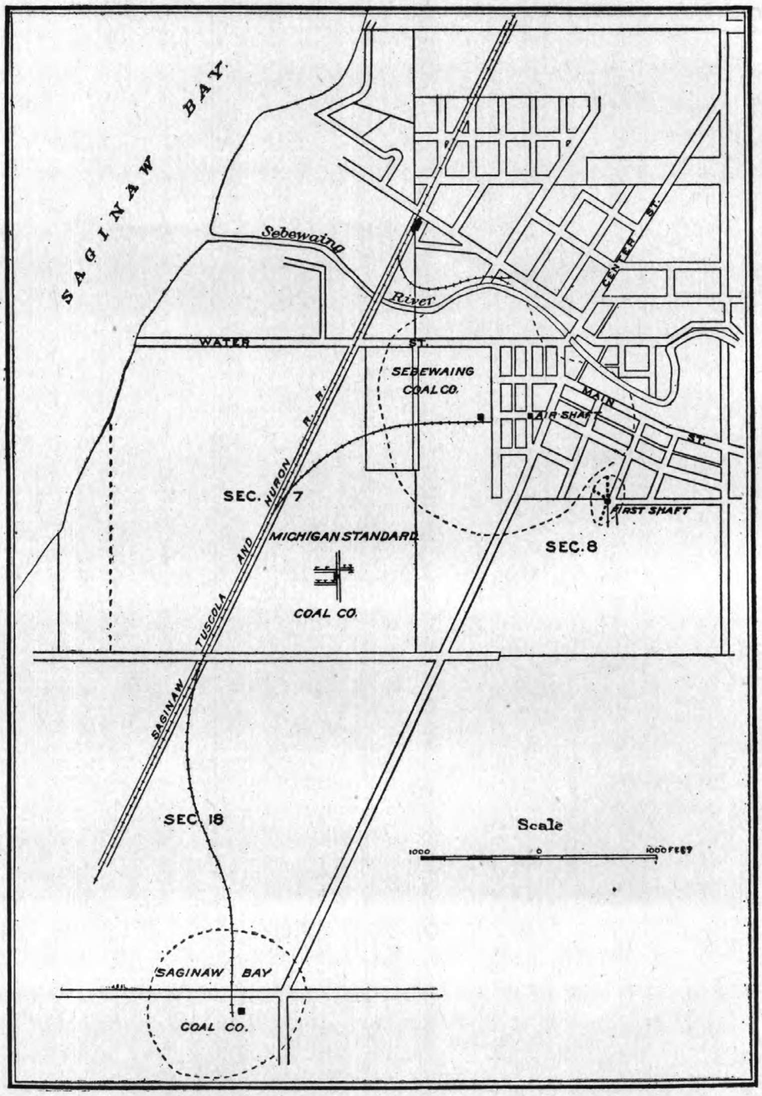


FIG. 29.—Sketch map of Sebewaing.

much over 3 feet, but the aggregate thickness of coal within 10 feet of strata may be 7 feet. Usually there are two seams, but sometimes there appears to be a third, which may be called the Upper Rider. On top of the coal of the Upper Verne the Lingula shale is very widely distributed, while above and between the coals black bituminous shaly limestones frequently show fossils preserved in pyrite.

Sections 1 and 2 of Pl. XXI show well the great variety of conditions which may exist at various points and the sharp rises and falls to which the coals are subject. A rise of 22 feet in 150, independent of any faulting, has been noticed in a mine. With such variations it is obvious that correlations are uncertain.

In consequence of these irregularities the working plans of the mines, which follow the troughs, are often very irregular, and since the merchantable coal is rarely over 4 feet thick, and often less than 2 feet thick, large areas of thin coal are left untouched.

The Verne coals have been extensively tested in the region west of Bay City, and they probably extend clear up to the Rifle River,

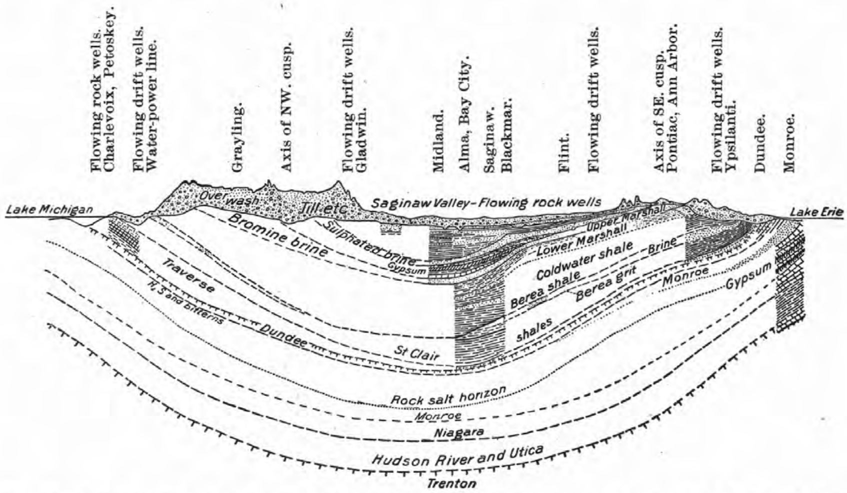


FIG. 30.—Cross section of the Lower Michigan basin, showing structure of the coal field and relation to artesian water flow. Horizontal scale, 1 mile=.135 inch; vertical scale, 1,200 feet=.321 inch.

but they are not always workable. They can be recognized as upper beds in the Saginaw district from Saginaw to St. Charles, though they do not appear so commercially important there. They are thick enough in patches, but the quality is poor. Usually they are from 100 to 150 feet below the surface. Sometimes they are less than 100 feet in depth, but are not ordinarily over 150. The Pittsburg Amelith shaft seems, however, to be on an unusually deep shoot of the Lower Verne. If the Lingula shale and the double coal seam may be safely counted as characteristic, they are a persistent horizon.

Below the Verne horizon comes the Middle Rider, a narrow and insignificant coal bed (perhaps a collective name for streaks of coal at various levels), unless, as is possible, the coal mines southeast of Saginaw in the Pere Marquette No. 1, Standard, and Saginaw mines

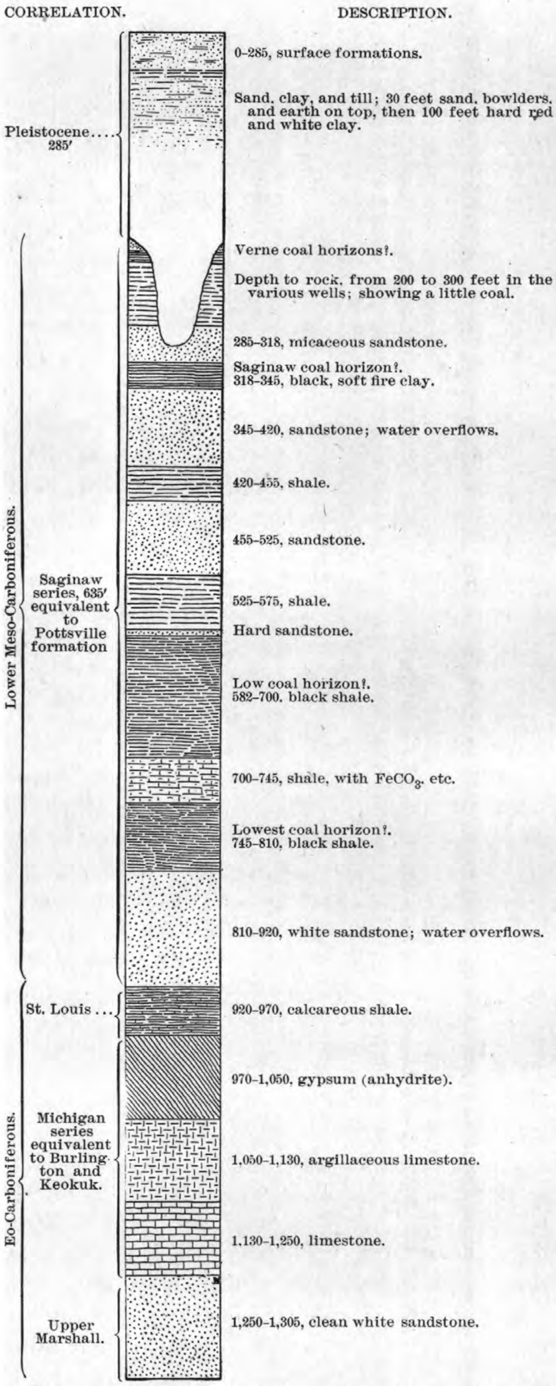


FIG. 31.—Section of well at Midland, Michigan. Altitude about 613 feet.

belong to this horizon. More probably, however, these mines are in an upward shoot of the Saginaw coal, which extends from West Saginaw to St. Charles and beyond at a depth of from 180 to 200 feet.

This Saginaw coal is different from the Verne coals, for it is noncoking and contains little sulphur; and if a light seam of bone coal, which frequently comes on top of it, is kept out, it is also low in ash. The fixed carbon is usually 50 to 55 per cent. This Saginaw coal runs frequently from 3½ to 5 feet in thickness. The coal mined southeast of Saginaw is of similar chemical character and thickness, and though it is 50 to 75 feet higher, there is a dip from the Pere Marquette No. 1 to the Saginaw shaft which, if continued, would carry it into the deep coal of the Chappell Fordney and the Pere Marquette No. 2. Moreover, a little farther east and northeast we come up against a big sandstone which replaces the coal, and there seems to be a tendency for the coal to rise and thin out in approaching the sand hills which replace it. When we come down to the Shiawassee field the coal which is worked at 80 feet or so appears to be the Verne coal, and there are signs of the Saginaw coal farther west around Owosso, while at Corunna we seem to be approaching the former shore line and sandstones have replaced the coal. The mines which were opened at Williamston may be in the Verne coals, for the Williamston coal seems to be similar in character to the Grand Ledge coal. From this point southward little workable coal is known, though there are records showing that coal fields extend continuously down to Jackson and that smaller beds of coal are not infrequent.

Very little is definitely known of the coals below the Saginaw, except that they exist. At St. Charles a few inches of coal were struck at 425 feet, and other occurrences are shown in Pl. XXI. Sometimes these coals are reported thick enough to work, but the greater depth adds materially to the expense of putting down borings enough to make sure of a workable body. There are no indications, either in the borings already made or in any theoretical considerations, that they are more persistent or uniform than the upper beds.

It is probable that the Saginaw coal is not so widespread as the Verne coals above it, from which it is frequently separated by a heavy sandstone. Owing to the irregularities of the basin in which the Coal Measures lie no accurate limitation can be made.

In the southeastern portion of the basin the Coal Measures are occasionally exposed in the streams. The coal beds are not deep, rarely over 400 feet, and so are not infrequently discovered in borings for artesian wells. To the northwest, however, the drift becomes thicker, there is less necessity for going into bed rock for water, and the expense of drilling is greater, so that little has been done to develop the field. Nowhere is the coal so uniform and continuous that one can safely begin to mine it without numerous borings close together. Consequently the initial expense of development will steadily increase as it is extended in that direction.

CHARACTER OF THE COAL.

ANALYSES.

The chemical character of the coals has already been referred to, since it is employed in correlating the different beds. The table of analyses shows that they are bituminous, leaning to the gas-coal type. The Saginaw coal has been highly recommended for fuel gas. The Verne coals, however, are much better coking coal, but are high in sulphur. No coal washing has been done, which might be profitable. The calorimetric tests show that the coal ranks with the Hocking Valley, but below the Pocahontas, and the results of boiler tests, which are given below, lead to a similar conclusion. The analyses and tests are taken largely from papers published by the writer in the Michigan Miner, of Saginaw.[a]

Analyses of Michigan coals.

No.	Location and name of coal.	Specific gravity.	Water.	Volatile combustible.	Fixed carbon.	Ash.	Sulphur.	Heating power in B. T. U.	Fuel ratio: fixed carb. ÷ volatile comb.
1	Pere Marquette, No. 1, Saginaw.	1.269	10.15	33.14	53.95	2.76	1.10	12,726	1.63
2	St. Charles, Somers No. 1	1.285	7.79	34.74	52.58	4.89	1.01	12,836	1.51
3	St. Charles, bone coal waste	......	8.08	30.74	49.29	11.89	.88	....	1.60
4	Owosso Coal Co	1.27	7.58	35.70	52.96	3.76	1.50	13,016	1.48
5	Corunna Coal Co., average sample	......	6.33	35.46	45.45	12.04	......	....	1.28
6	Jackson, New Hope mine	1.247	5.58	46.73	45.28	2.41	2.83	13,569	.97
7	Saginaw Co., Verne	1.32	5.82	39.79	45.15	9.24	3.83	12,861	1.13
8	Sebewaing, Michigan Standard mine	1.34	6.09	39.54	46.06	8.26	5.72	12,714	1.16
9	West Bay City, Monitor mine	......	10.03	35.36	49.94	4.64	1.12	....	1.41

1. From main seam (32 inches) of the Pere Marquette No. 1 shaft, recently abandoned, all the coal with sufficient roof having been mined. Depth about 135 feet. Probably the Saginaw seam, as mined also in the Saginaw and Standard mines nearby. Analyst, H. J. Williams.
2. From J. H. Somers No. 1 shaft, St. Charles, excluding the top cannel or bone coal. At the point where sample was taken there were 35 inches sampled and 3 inches of top "cannel coal." Analyst, H. J. Williams.
3. "Top" bone coal, 8 inches, at Robert Gage Coal Company's shaft, St. Charles. Analyst, F. S. Kedzie.
4. Coal of the Owosso Coal Company, 33 inches. Analyst, H. J. Williams.
5. Average analysis of the coal of the Corunna Coal Company.
6. Sample lump from the New Hope mine, Jackson. Analyst, H. J. Williams.
7. Sample from Verne mine, Saginaw County. Analyst, H. J. Williams.
8. From the Michigan Standard mine, Sebewaing. Analyst, H. J. Williams.
9. From the Monitor mine, West Bay City. Analysts, Lathbury and Spackman.

[a] For a much fuller treatment of the chemical character of the coal, as well as other matters, see paper by the writer on the coal of Michigan: Part II of Vol. VIII of Reports of Geological Survey of Michigan.

BOILER TESTS.

Boiler trial by E. C. Fisher on one Wickes's patent water tube safety steam boiler.

	Saginaw.	Hocking Valley.
Fuel:		
Total amount consumed .... lbs..	6,092.0	5,808.5
Moisture in coal .... per cent..	5.5	5.0
Dry coal consumed .... lbs.	5,757.0	5,518.08
Dry coal consumed .... per cent..	4.2	6.1
Total refuse .... lbs..	245.5	338.5
Total combustible .... lbs..	5,511.5	5,179.5
Dry coal consumed per hour .... lbs..	575.7	551.808
Combustible consumed per hour .... lbs..	551.15	517.95
Results of calorimetric tests:		
Quality of steam	.9925	.9927
Percentage of moisture .... per cent..	.75	.73
Economic evaporation:		
Water actually evaporated per pound .... lbs.. Dry coal .... lbs.. Actual temperature and pressure .... lbs..	6.93	6.99
Water evaporated per pound dry coal from and at 212° F .... lbs..	8.26	8.32
Water evaporated per pound combustible from and at 212° F .... lbs..	8.63	8.87
Rate of combustion:		
Dry coal burned per square foot grate per hour ... lbs..	25.5	24.5
Dry coal burned per square foot water-heating surface per hour .... lbs..	.363	.34
Rate of evaporation:		
Water evaporated from and at 212° F. per square foot grate surface per hour .... lbs..	211.04	204.1
Water evaporated from and at 212° F. per square foot water-heating surface .... lbs..	3.00	2.90
Commercial horsepower:		
On basis of 34.5 pounds water evaporated per hour from and at 212° F .... horsepower..	137.9	133.2
Builder's rating .... horsepower..	144.0	144.0
Cost in coal to evaporate 100 pounds of water from and at 212° F	\$0.14$\frac{4}{10}$	\$0.15$\frac{8}{10}$
Cost of coal per ton (2,000 pounds)	\$2.25	\$2.50
Water evaporated from and at 212° F. per pound wet coal .... lbs..	7.80	7.91
Efficiency of boiler .... per cent..	71.10	....

Lansing waterworks tests.

No.	Name of coal.	Grade of coal.	Pounds of coal burned during test.	Pounds of ashes.	Pounds of water evaporated from 110° F.	Pounds of water evaporated per pound of coal.	Price of coal per ton, delivered.	Pounds of water evaporated for $1 of fuel.	Remarks.
1	Cedargrove	Steam lump	8,471	804	62,581	7.387	$2.45	6,030	No clinkers; light brown smoke.
2	Goshen Hill	Run of mine	10,162	995	71,433	7.030	2.25	6,248	Light clinkers; smoke medium.
3	Black Diamond	do	11,106	1,293	70,875	6.381	2.26	5,647	Clinkers bad; heavy, dark smoke.
4	Massillon	do	10,407	808	72,547	6.971	2.33	5,932	Light clinkers; smoke medium.
5	Hocking lump	do	11,163	949	74,400	6.634	2.35	5,646	No clinkers; light smoke.
6	New River	do	8,765	524	68,471	7.852	3.20	4,907	No clinkers: light brown smoke.
7	Hocking Valley	do	10,706	808	71,618	6.689	2.31	5,791	No clinkers; smoke medium.
8	Cedargrove	do	10,000	1,048	65,614	6.561	2.35	5,583	Clinkers and smoke medium.
9	Hocking Valley	Pea	12,845	1,558	75,332	5.864	1.94	6,046	Clinkers and smoke heavy.
10	Mingo	Run of mine.	9,669	682	71,486	7.393	2.80	5,281	No clinkers; very little smoke.
11	Jackson Hill	do	10,397	513	71,185	6.846	2.50	5,477	No clinkers; heavy smoke.
12	Riverside	do	9,062	491	74,280	8.196	2.60	6,304	No clinkers; very little smoke.
13	Hocking Valley	do	11,645	1,021	74,899	6.432	2.34	5,497	Clinkers medium; smoke heavy.
14	Saginaw	do	10,754	895	67,471	6.274	2.20	5,703	Clinkers and smoke medium.
15	Corunna	do	15,551	1,440	59,520	5.632	2.25	5,006	Clinkers and smoke bad.
16	South Side	do	7,896	565	63,076	7.988	2.50	6,390	No clinkers; smoke medium.
17	Wellston shaft	do	8,405	120	64,066	7.622	2.25	6,775	No clinkers; smoke medium.
18	Pocahontas	do	7,089	285	65,428	9.229	3.00	6,153	No clinkers; very little smoke.
19	Not known	do	10,073	1,097	65,862	6.538	2.09	6,317	No clinkers; smoke heavy.
20	Willliamston	do	{11,178	......	62,335	5.659	2.40	......	
			10,391	440	62,015	6.021	......	......	

DEVELOPMENT.

HISTORY.

The southern portion of the coal field was the first part of the State to be settled. The Jackson district was the first to become a coal producer, in 1835, though the neighborhood of Grand Ledge presses it hard for this honor, coal having been produced here in 1838. The Jackson field was for a long time the only one which was quoted for commercial production, and the light, rather superficial gas coal, high in sulphur, which is found there was taken to represent the Michigan coals in general. In 1878, however, the Corunna Coal Company began prospecting in the neighborhood of Corunna, and work has continued there ever since. In 1889 coal was struck at a depth of 85 feet in a well put down in the southern part of Sebewaing, and the Saginaw Bay Coal Company was formed for its development. Much difficulty was experienced with water, as this is a region of strong artesian wells. After a few years this company was succeeded by the Sebewaing Coal Company, and this, too, succumbed on account of the water, but mining is still continued by the Michigan Standard Coal Company, and the J. C. Liken Coal Company has been recently organized.

Coal was encountered in many of the old salt wells, including the first one put down in Saginaw and the first at Bay City, drilled by William Walker in 1861. In 1866 the Pioneer Coal Company was organized, and in 1876 the Eureka Coal Company tried to develop the Rifle River region. But no commercially successful mining was done until there came a critical time in the history of the Saginaw Valley, when the lumber industry, which had hitherto supplied cheap fuel, was decadent, and the twin industry of salt manufacture bade fair to share its fate unless some other source for the cheap fuel which had been furnished by the waste of the lumber could be found. The Saginaw Board of Trade spent more than $1,000 in boring for coal, with hopeful but hardly satisfactory results. Boring had also been done in Bloomfield, east of Saginaw, which resulted in finding coal, but not under very favorable conditions. The impetus toward successful coal mining at Saginaw was really given by a well for water, put down in the southeast part of the city in 1895. On the strength of this report the Saginaw Coal Company was organized to do further boring. This proved a success, and after it was reported that one-third interest had been sold for $100,000 there was no further difficulty in securing capital for coal explorations. The J. H. Somers Coal Company, attracted by a car of Saginaw coal, continued the explorations which had been begun around St. Charles, and, going through the Verne, which seems to have been the coal generally struck up to this time, located the Saginaw seam. Since then four other shafts have been put down in the vicinity of the Somers No. 1 shaft.

Entirely independent is the history of the Verne mine and the Colcord mine on section 23 of Albee Township, east of St. Charles. These were the first mines worked in Saginaw County, but being on the Verne seams, far from railroads, and operated by people of little means, and the quality of the coal being much the same as at Jackson, they never proved successful, though the Verne is still supplying the local trade on tribute. About the same time an attempt was made not far off, at Elk, Genesee County, to start a mine by a slope.

The Monitor, the first of the coal mines of Bay County, was started by the coal struck in a well put down for water at Zill Brothers' saw-mill in 1893.[a]

METHODS OF MINING AND CHARACTER OF LABOR EMPLOYED.

Until within the last few years there has been very little variety in the methods of mining. With the exception of one mine at Jackson and failures at Corunna and Elk, and the little drifts hardly larger than burrows at Grand Ledge, there has been no mining other than by shafts. Very commonly balanced skips are employed. Sometimes there is a cleat in the coal, but usually not very much, and the mine entries have been laid out to the cardinal points or so as to follow the valleys or thickest parts of the coal. The Porter coal mine shows the extreme irregularities of many of the old workings where little mapping was done and no instruments used until after the mine had been laid out, if, indeed, any mapping was done at any time. In many cases there was absolutely no record of the mine workings whatever, and in one well-known case, at Sebewaing, when it was found that a mine had worked into land for which the operator had no lease, there was no method of accurate redress. Since the industry has grown in the last two years, matters are in much better shape in the larger mines, but it is doubtful yet if over 50 or 60 per cent of the probable coal in the area of the mine is won. The pillar-and-chamber system is practically the only one used. There has been some trial of the panel system, and the Verne mine did for a time try the long-wall system. The objections to the long-wall system have been, first, the fear of shattering the roof and letting in water, which has always been one of the most formidable foes in this field, and second, the difficulty of getting miners and cars enough to insure steady operation, which is essential to economy in this system. Lack of cars has been a chronic complaint for the last five years.

The workmen are from various districts; more than half of them are American born, and those not native have been on an average sixteen years in the United States. The location of the mines near large cities has in most cases done away with the necessity for a company store and the consequent friction. The workmen of the mines around Bay City and Saginaw scatter through the population of the city and make no distinct class by themselves. For tramming, mules are used; not as yet steam or electricity.

With few exceptions the land has not been bought outright for mining, as it is valuable for agricultural purposes. It is customary to lease the land at a royalty of about 8 cents per ton, while there has been some difference of opinion as to whether a ton should be reck-

[a] Two pamphlets by C. B. Schaefer and the Saginaw Evening News of July 23, 1898, contain much historical information concerning Michigan coal mining.

oned mine run or lump coal. The miners and operators are not admitted into the Ohio convention, but meet in Saginaw to arrange their own scale. The rate of mining was based, in March, 1901, on 86 cents per ton. The cost to the companies is not far from $1.30 per ton. Mine cutting machines were first introduced and are most extensively used in the Bay City field. The Harrison air machine seems to be the most used at present. The smaller mines, especially, run more in winter, when there is less other work and more demand for fuel.

STATISTICS OF MINE PRODUCTION.

A glance at the statistics, illustrated by fig. 32, shows a very rapid growth in the industry in Michigan, and also shows that the growth is very largely confined to a few concerns. The following tables give the essential facts:

Production of coal in Michigan by decennial periods.

1880:	
Production .... short tons..	100, 800
Value	$224, 500
Average price per ton	$2. 22
1890:	
Production .... short tons..	74, 977
Value	$149, 195
Average price per ton	$1. 99
Decrease of 1890 from 1880:	
Production .... short tons..	25, 823
Per cent	26
Value	$75, 305
Per cent	34
1900:	
Production .... short tons..	849, 475
Value	$1, 259, 683
Average price per ton	$1. 48
Increase of 1900 over 1890:	
Production .... short tons..	774, 498
Per cent	1, 033
Value	$1, 110, 488
Per cent	744

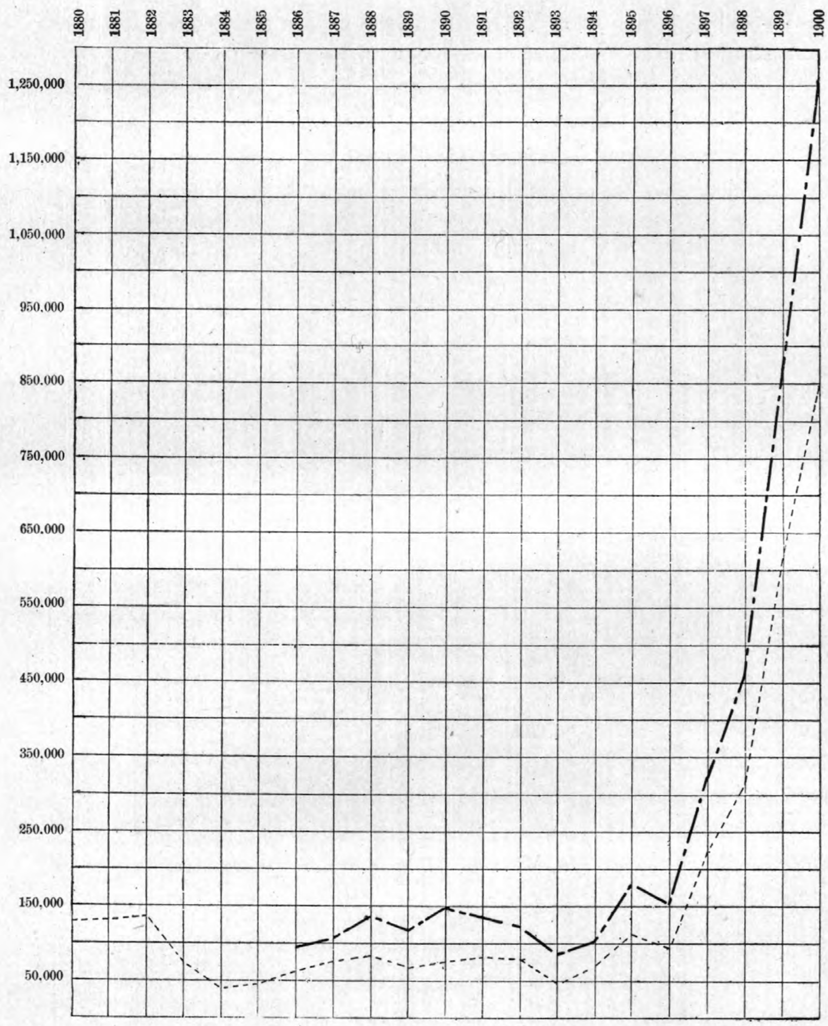


FIG. 32.—Diagram showing production and value of coal produced in the Northern Interior field by years from 1880-1900, inclusive.

------- Michigan. —·—·— Total value.

Scale { 50,000 tons to the square. $50,000 to the square.

Production of coal in Michigan, 1880–1900.

Year.	Production.	Value.	Year.	Production.	Value.
	Short tons.			*Short tons.*	
1880	129,053	Not given.	1891	80,307	$133,387
1881	130,130		1892	77,990	121,314
1882	135,339		1893	45,979	82,462
1883	71,296		1894	70,022	103,049
1884	36,712		1895	112,322	180,016
1885	45,178	$75,000	1896	92,882	150,631
1886	60,434	90,651	1897	223,592	325,416
1887	71,461	107,191	1898	315,722	462,711
1888	81,407	135,221	1899	624,708	870,152
1889	67,431	115,011	1900	849,475	1,259,683
1890	74,977	149,195			

Production of coal in Michigan for 1900, by counties.

County.	Production.	Value.
	Short tons.	
Bay	190,814	$283,184
Eaton	4,530	8,770
Genesee	300	300
Huron	5,953	11,142
Jackson	23,317	43,388
Saginaw	601,112	872,486
Shiawassee	23,449	40,413
Total	849,475	1,259,683

PROSPECTIVE DEVELOPMENT.

It is expected that a number of mines will increase their output during the coming year. Three or four of the shafts have been so recently put down that they hardly count for anything yet in the way of output. With the equipment now on hand an output of 8,000 tons a day might be reached in the coming year. Not only are the present mines increasing their output, but the work of drilling goes on in new fields. Moreover, though the output for the last twelve months was less than a million tons, the miners worked on an average of but one hundred and eighty days in the year. The growth of other industries in Michigan, such as those of salt, glass, and cement, will make a steady and growing demand for coal. The Hecla Cement Company, of Bay City, has invested largely in coal lands, and the Twentieth Century Cement Company, of Fenton, has bought out the Owosso Coal Company. Since cement factories and sugar refineries are springing up all over the State, an ample outlet for increased supply is at hand.

DISTRIBUTION.

LOCATION AND CHARACTER OF MARKETS.

Reports from the various mines show that the local market is, for most of the mines, especially the smaller ones, a most important one; in fact, this may be said to be true of all except the Bay City, Saginaw, and St. Charles mines. Many of the mines, such as those at Jackson, Grand Ledge, and Verne, load directly into wagons and have no railroad trade. Even in Bay County a very large proportion of the coal is taken by the alkali works, shipbuilding, and other industries, and the Saginaw coal is the only one that goes far afield. A glance at the map (Pl. XX) shows that the coal does not work far south, but rather to the northwest, the result being that it does not come into competition with the Ohio coal, and stands an even advantage as regards freight rates. In fact, since there are many empty cars to be hauled west, the railroads can afford to carry it across Lake Michigan and in the direction from which the wheat comes east at the very lowest rate. In consequence we find it spreading as a counter current into Wisconsin, Minnesota, and even as far west as the Dakotas. The car ferries across Lake Michigan are very important in this distribution.

Reports from the various mines are not sufficiently full to warrant a statement regarding the different grades of the product. From a half to a third of the output is slack, which is burned at the mines or used in factories. The lump is used on railroads and for domestic use. The coal exported from the State has not exceeded 100,000 tons a year.

ROUTES AND POINTS OF CONSUMPTION.

The coal field is well supplied with transportation by railroad, while Saginaw Bay and Saginaw River bring lake transportation to the heart of the coal basin. It would require nothing but dredging to bring the water transportation to St. Charles, because the water level is there practically that of the Great Lakes.

The chief railroads now engaged in the coal business are the Pere Marquette, which serves many of the Bay City mines and those at Saginaw, and the Michigan Central, which serves most of the Bay City mines and those at St. Charles. The Detroit and Mackinac, a local road to Alpena, having traffic arrangements with the Pere Marquette, reaches the Wenona and Handy Brothers mines. The Grand Trunk, by the Cincinnati, Saginaw and Mackinaw, might also reach most of this coal business, but has done little except for the Verne and Standard mines. The Grand Ledge mines are on the Pere Marquette, but are not large shippers by rail. The Sebewaing mines are on the Pere Marquette system. Around Owosso and Corunna it is comparatively easy to reach three or four different systems, but practically the Grand Trunk (Detroit, Grand Haven and Milwaukee) does the business. The rates are relatively high, as may be shown from the fact that it costs 70 cents per ton to ship from Bay City to Lansing, and only $1.40 from the Hocking Valley district, which is four or five times as far away. The result is that the coal worth $1.35 at the mine in Bay City will cost $2.05 in Lansing, and coal worth 65 cents in Ohio will command the same price, and as a matter of fact these are about the figures of competition.

THE WESTERN INTERIOR COAL FIELD

BY

H. F. BAIN

CONTENTS.

ILLUSTRATIONS.

THE WESTERN INTERIOR COAL FIELD.

By H. F. Bain.

GEOGRAPHIC RELATIONS.

LOCATION AND BOUNDARIES.

The general location of the Western Interior field and its boundaries and relations to political subdivisions are shown on Pl. XXII. The field lies within the prairie plains of the Mississippi Valley and is a portion of a great featureless plain having no marked geographic division. Such divisions as are recognized are mainly political and commercial. Geologically the field may be divided into two portions, as shown on the map. The differences between these two portions, which are more accentuated in the northern part of the field and fade out toward the south, will be discussed later. The political subdivisions—States, counties, etc.—are also shown on the map, as well as the inspection districts recognized in Iowa and the wage-scale districts of the same State. In Missouri and Kansas only one inspection district is recognized in each State. In neither of these States are there regular wage-scale districts. The production of coal in Nebraska is exclusively for local use, and the quantity is so small and the supply so irregular that for present purposes the Nebraska portion of the field may be entirely neglected.

The commercial subdistricts of the Western Interior field are too poorly defined to be represented on a map. The reasons for this and the extent to which such districts may be recognized will be discussed in connection with the description of the individual coal beds.

PROBABLE EXTENT.

Much of the Western Interior coal field has not as yet been accurately surveyed and its extent must be estimated. The figures given below are believed to closely approximate the truth.

Area of Western Interior coal field.

State.	Total area.	Probably productive.
	Sq. miles.	*Sq. miles.*
Iowa	20,000	10,000
Nebraska	3,200	....
Missouri	23,000	14,000
Kansas	20,000	15,000

In Iowa and Missouri the probably productive area estimated above essentially corresponds to the area represented on the maps as underlain by the Lower Coal Measures. In Kansas it includes the corresponding region and in addition a portion of the area underlain by the Upper Coal Measures, which are not discriminated from the Lower Coal Measures on the map. It is not intended to imply either by the maps or in the text that all of the area outlined will yield coal. Much of it will undoubtedly prove barren, since the coal of this field is characteristically patchy and irregular in distribution. The probable productive area noted above is the area of essentially productive as distinguished from essentially barren measures. The exceptions will be noted in detail later.

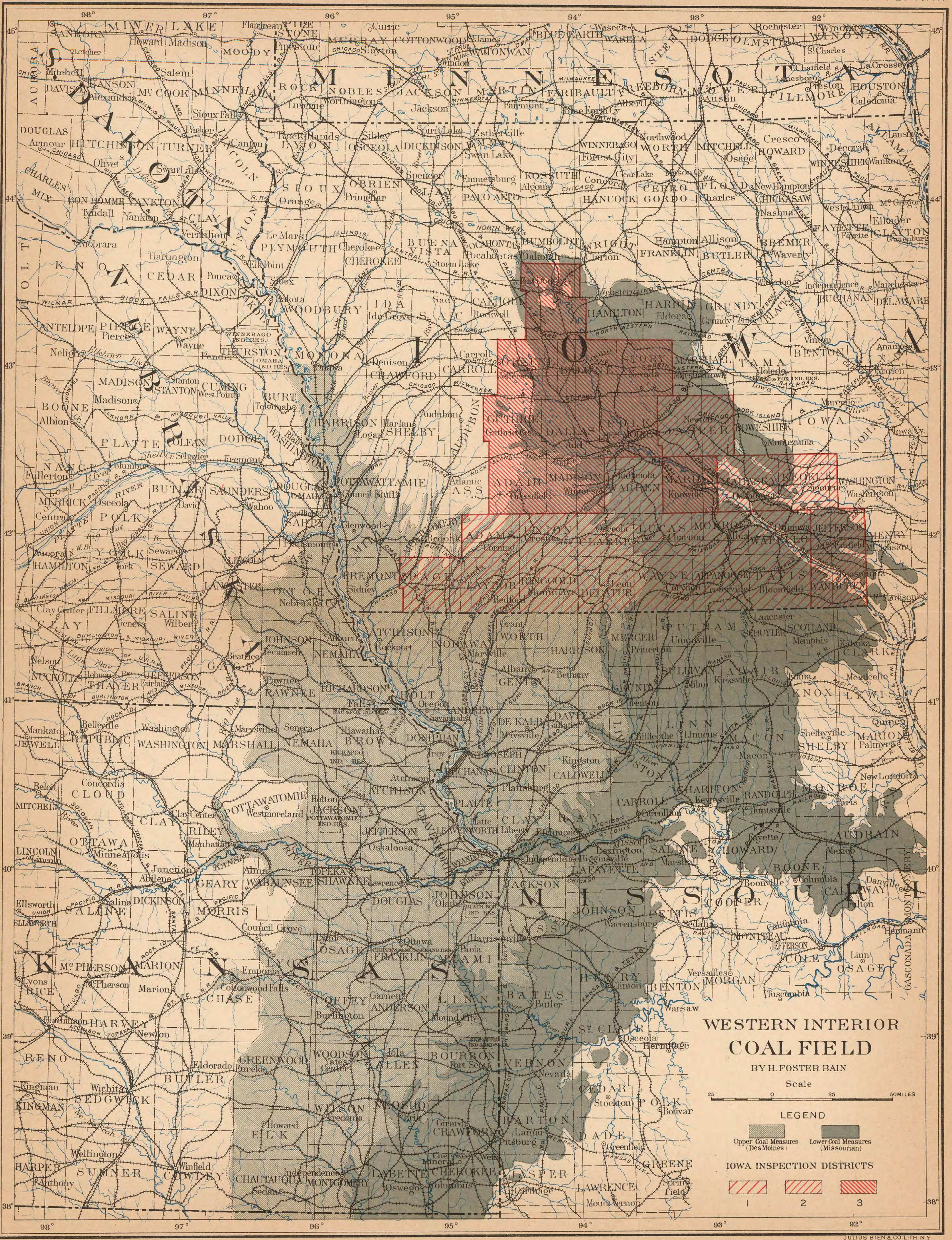
GEOLOGIC RELATIONS.

AGE OF COAL-BEARING ROCKS.

The Coal Measures of the Western Interior field are of Carboniferous age. More specifically, they belong to the upper portion of the rocks of the Carboniferous system, that portion to which the terms Upper Carboniferous and Pennsylvanian series have been applied. They rest unconformably upon the rocks of the Lower Carboniferous or Mississippian series. They are covered in Kansas and Nebraska by the Permo-Carboniferous beds, which are conformable with them. In Iowa Cretaceous deposits rest unconformably on them, and in Iowa, Nebraska, northern Missouri, and northeastern Kansas the drift and associated deposits of the Pleistocene cover the coal-bearing strata.

STRATIGRAPHY.

The Coal Measures of this field include limestones, sandstones, shales, fire clays, and the coal beds proper. Limestones are probably least abundant, and shales in their various phases—argillaceous, bituminous, calcareous, and arenaceous—most abundant. In the northern portion of the field limestones and calcareous shales are notably more abundant in the upper or barren portion, and less so in the lower or productive portion. In Kansas the distinction between the two divisions is not



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so well preserved, and in the adjacent Southwestern coal field it quite loses value. In a general way there is a prevailing dip to the west of 10 to 20 feet per mile. In detail the dip is south to southwest in Iowa, west to northwest in Missouri, and predominantly northwest in Kansas.

The Coal Measures of this field increase in thickness westward from their outcrop. There is also a gradual increase in maximum thickness from north to south. In Iowa the maximum thickness measured is 1,060 feet.[a] In Missouri Winslow has estimated the total thickness at 2,000 feet.[b] In Kansas Haworth gives 3,000 feet as the thickness.[c]

On the maps accompanying this report (Pls. XXII–XXIV) two divisions of the Coal Measures are represented. These are the Upper and Lower Coal Measures. In Iowa and Missouri the terms Des Moines and Missourian, respectively, are used for the two divisions. In Kansas these terms have not been used, although essentially the same division is recognized. The basis of the division is largely lithologic and economic. The Coal Measures in this field belong to one series and represent a continuous sequence of deposition. The faunal change at the dividing line is slight, but the division is none the less valid and important. The Lower Coal Measures include the bulk of the productive coal beds throughout the field. From 93 to 98 per cent of the coal mined comes from them. These beds are relatively thick, are notably irregular, and show a patchy distribution. They are associated with thick sandstones, thick bodies of shale, particularly of bituminous and argillaceous types, and with thin and unimportant limestones. The Upper Coal Measures include a few very thin beds of coal of great regularity and extent. They are associated with little sandstone, and with shales usually calcareous or argillaceous in type. The measures also include a notable number of thick and persistent limestones. As already stated, these differences are not pronouced to the south, though even here the general relations are as stated above. The dividing line is drawn at the base of an important limestone, 40 to 80 feet thick, known variously as the Winterset, Bethany, or Erie. The general equivalence of these three terms is well recognized, though there is as yet some doubt as to the exact correlation of this and other minor divisions.[d] Subdivisions of both the Upper and Lower Coal Measures have been systematically recognized and mapped in Kansas by Haworth and his associates.[e] In Missouri, corresponding divisions have been recognized and partially mapped by Keyes[f] and Marbut.[g] In Iowa,

[a] W. H. Norton, Iowa Geol. Survey, Vol. VI, p. 333.
[b] Mo. Geol. Survey, Vol. I, Prel. Rept. Coal, p. 24.
[c] University Geol. Survey, Vol. III, p. 20.
[d] E. Haworth, Univ. Geol. Surv. Kansas, Vol. III, pp. 101, 102.
[e] Univ. Geol. Surv. Kansas, Vols. I and III.
[f] Bull. Geol. Soc. Am., Vol. XII, pp. 173–196.
[g] Missouri Geol. Surv., Vol. XII, Clinton, Calhoun, Lexington, Richmond, and Huntsville sheets.

divisions of the Lower Coal Measures have been recognized,[a] but have not been mapped except in Appanoose County.[b]

The divisions recognized in each State and their approximate correlation are shown in the following table. Keyes has suggested more exact nomenclature and corelation.[c] His suggestions have not as yet been followed in mapping.

Divisions of the Lower Coal Measures.

Kansas (Haworth).		Missouri (Keyes).	Iowa (Geological Survey).
Pleasanton	Marmaton.	Marais des Cygnes	Pleasanton.
Altamont			
Pawnee		Henrietta	Appanoose and equivalents.
Labette			
Fort Scott[1]			
Cherokee		Cherokee	Cherokee.

[1] The name Fort Scott limestone was applied by Swallow (Prel. Rept. Geol. Surv. Kansas, 1866) to a heavy bed of limestone at Fort Scott, Kans. Subsequently the name Oswego limestone was used by Haworth and Kirk (Kansas Univ. Quart., Vol. II, p. 105) for two beds exposed at Oswego, the upper of which is the same as the Fort Scott. In subsequent publications the statement is made that the name Fort Scott is equally applicable. The lower member is called the Fort Scott cement rock and the upper the Fort Scott limestone, and for the two the name Oswego is used. (Haworth, Vol. III, p. 30.)

Oswego had already been used by Prosser (Bull. Geol. Soc. America, Vol. IV, pp. 100, 108, 116) as the name of a formation in the Silurian of New York, and is therefore preoccupied. Inasmuch as the name Fort Scott has been extended to the lower of the two members and was proposed by Swallow for the upper and more important one, it is here accepted as a formation name for these closely associated limestones.

It will be seen that the Lower or Productive Coal Measures are made up of three divisions. The Uppermost, the Pleasonton shales, including the Altamont limestones, attain a thickness in Kansas of 200 feet. To the north they thin, until in central Iowa they are hardly to be separated from the next lower member. In Kansas they have been grouped with this middle division by Haworth under the name Marmaton formation.[d] The middle member passes under various names in different parts of the field. In Kansas it includes the Pawnee and Fort Scott limestones, with the intercalated Labette shales, and has an approximate thickness of 150 feet, a thickness which it maintains well to the north. In southwestern Missouri the shale member of the sequence is unimportant; and the limestones, the Henrietta formation of Keyes,[e] form a single escarpment, which may be seen near Hume, in Bates County. In northern Missouri and southern Iowa the formation includes a number of thin limestones separated by shales and

[a] Iowa Geol. Surv., Vol. V, pp. 374-398; Vol. VI, p. 585; Vol. VIII, p. 82.
[b] Iowa Geol. Surv., Vol. V.
[c] Bull. Geol. Soc. Am., Vol. XII, pp. 173-196.
[d] E. Haworth, Univ. Geol. Surv. Kansas, Vol. III, Pt. VI, 1898.
[e] Bull. Geol. Soc. Am., Vol. XII, 1901, p. 176.

carrying thin coal seams. This is the phase of the formation which has been called the Appanoose. In central Iowa there are beds equivalent to the Henrietta, but the sequence of strata is different.

The lowest member of the measures is the Cherokee shale, which outcrops in a crescent-shaped area following the outer lines of the outcrop of the Coal Measures from Kansas to north-central Iowa. The shales vary in thickness from 200 to 600 feet along the outcrop of the next higher formation and thin to nothing at their own outcrop. The formation is made up largely of shale and sandstone and carries numerous important coal beds. The individual strata vary in thickness and character from point to point, so that it is impossible to construct a general section of more than local value. In the southwest, especially in southeastern Kansas and the adjacent portions of Missouri, the beds are apparently more regular than elsewhere, and the irregularities found farther north serve to mark this as an exceptional portion of the field.

STRUCTURE.

The structure of the field is quite simple. The prevailing dips have already been given. Locally, more important dips occasionally occur, but they are relatively rare. There are numerous and important irregularities in the coal beds proper, but these are principally due to conditions prevailing at the time of their deposition rather than to later deformation.

THE COAL.

NUMBER AND EXTENT OF WORKABLE BEDS.

In the Western Interior field the coal is very irregularly developed along the various coal horizons. Indeed, it has so far proved impossible to make a general section showing even the coal horizons which would be of more than local value. This patchy distribution of the coal is not the result of later faulting or other dynamic phenomena, but is due to the conditions under which the coal was accumulated. The bulk of the coal mined, 80 to 90 per cent, is taken from the Cherokee shales. From 10 to 18 per cent is from the other divisions of the Lower Coal Measures. The remainder is from the Upper Coal Measures. The coal beds of the Cherokee shales are much more irregular than those found higher in the series. They are also much thicker. They, however, thicken and thin very rapidly, varying from nothing to 7 feet in a horizontal distance of a few feet. The usual variation is from 18 inches to 6 feet. The thicker workable beds lie in basins or troughs of very irregular outline. The coal varies a little in elevation, differences of 20 to 30 feet being common, and as much as 60 feet of local dip being observed in a single mine. Usually the coal thins to the rise, and it seems that irregularities are a result of original irregularities of the bottom over which the coal accumulated. In the case of the lower coal worked near What Cheer, in Iowa, the inequalities can be referred to the irregularities of the old erosion surface of the St. Louis limestone, upon which the Coal Measures rest unconformably.[a] This condition is paralleled by the outlying pockets of very thick coal found in Missouri along the borders of the field, and described by Winslow.[b] In some of these pockets coal 70 feet thick has been found, but its extent is very limited. The coal occurs in narrow channels eroded in the earlier rocks. In one instance such a channel is known to be 100 feet wide, and has been followed for 500 feet. These pockets have attracted much attention, but are really of small value. Their exploitation has entailed the loss of considerable money.

With but few exceptions the individual coal beds, particularly in the Cherokee shales, are so limited in extent and so variable in characteristics that they do not support distinctive mining districts. Probably the most notable exception is the Cherokee coal of southeastern Kansas and adjacent portions of Missouri. The principal mines are in Cherokee and Crawford counties, Kans., and include the Frontenac, Pittsburg, Scannon, Wies City, and neighboring collieries.[c] The coal was at first mined by stripping, but is now won through shafts 60 to 90 feet deep. The coal underlies an elliptical area with the longer diameter trending northeast to southwest. The southeastern limit is determined by the outcrop of the coal itself. The distance to which the coal extends down the dip to the northwest is undetermined, but apparently it does not occur as far as Girard. To the northeast it thins out within a few miles of the State line. To the southwest it extends as far as Mineral, and possibly much farther. The Cherokee coal is excellent in quality. The bed has a variable thickness of from 3 to 10 feet, with a general average of 40 to 42 inches. There is a good roof of black slate and a fire-clay bottom. The coal has an even dip, but mining is complicated by the presence of a number of clay slips and horses.

In general in the area of the outcrop of the Cherokee shales the distribution of mining camps is controlled primarily by the location of transportation lines. The region is an open plain, and the only surface inequalities are those due to stream erosion. The main railway lines cross the country from east to west, and where they pass over the area of the Cherokee shales large mines are developed. For example, in Iowa the Fort Dodge mining district is located where the Illinois Central and Minneapolis and St. Louis railways cross this belt of shale. The Boone mines occupy a similar position with reference to the Chicago

[a] Iowa Geol. Surv., Vol. IV, 1894, pp. 255–311.
[b] Missouri Geol. Surv., Prelim. Rept. on Coal, 1891, pp. 167–172.
[c] For details see W. R. Crane, Univ. Geol. Surv. Kansas, Vol. III, 1898, pp. 119–128, 151–154.

and Northwestern. The Des Moines mines are on the main line of the Chicago, Rock Island and Pacific. The Oskaloosa mines are on the Iowa Central and branches of other lines. The main line of the Chicago, Burlington and Quincy is marked by big mines from Ottumwa to Cleveland. Huntsville, Mo., is on the Wabash Railway. The location of the Rich Hill mines, in the southwestern part of the same State, was determined by an important line of the Missouri Pacific. The Leavenworth mines reach a horizon broadly equivalent to that of the thicker coals mined in the area of the outcrop of the Cherokee shales. The mines are interesting because of their depth—713 to 850 feet—which is somewhat exceptional for this field. They offer encouragement to the idea that at least some of the coal horizons now mined near their outcrop will prove productive to considerable distances under cover. Numerous deep drill holes show, however, that the coal is quite as irregularly distributed here as in that portion of the field now developed. A section of the coal at the Lansing shaft in the Leavenworth field is as follows:[a]

Section at Lansing shaft, Kansas.

	Feet.
5. Shale	28
4. Coal	2
3. Fire clay, changing below to shale	25
2. Coal	2
1. Fire clay.	

The beds above the Cherokee shale are much more regular in structure, and the coals, while thinner, are marked by greater continuity. One of the most important of these coals is found in southern Iowa and northern Missouri. It is known as the Mystic or Centerville coal, and underlies about 1,500 square miles. A general section of this bed and accompanying strata is as follows:

Section of Mystic or Centerville coal.

	Feet.	in.
7. Limestone, gray, fossiliferous, "cap rock"	2	10
6. Shale, bituminous, fissile	1	0
5. Coal	1	6
4. Clay parting	0	2
3. Coal with a thin band of pyrite near the base	1	0
2. Fire clay	1	6
1. Limestone, heavily bedded	2	10

This coal is extensively mined in Appanoose and Wayne counties, Iowa,[b] and in Schuyler, Putnam, and Adair counties, Mo.[c] The Lexington coal, mined in Lafayette and Ray counties, Mo.,[d] occupies the same relative position in the Coal Measures. The section of this coal

[a] W. R. Crane, Univ. Geol. Surv. Kansas, Vol. III, 1898, p. 181.
[b] Iowa Geol. Surv., Vol. V, pp. 363–438.
[c] Missouri Geol. Surv., Prel. Rept. on Coal, 1891, pp. 54–62.
[d] Missouri Geol. Surv., loc. cit., pp. 110–112, 117–123.

as exposed at Higginsville is strikingly like that of the Mystic coal already given. For purposes of comparison it is given below:

Section at Higginsville.

	Feet.	in.
9. Limestone.		
8. Shale, black, fissile	1	11
7. Coal	0	5
6. Clay parting	0	½
5. Coal	0	8½
4. Clay	0	½
3. Coal	0	3
2. Fire clay	1	0
1. Limestone.		

In Kansas the horizon equivalent to that of the Mystic and Lafayette coals—the Labette shale—is not known to carry any workable coal. At higher horizons thin beds of coal are worked, notably in the southeastern part of Linn County and northeastern Bourbon, while a bed 16 to 30 inches thick supplies the local market. Near Ransomville, in Franklin County, and in the vicinity of Atchison, coal is also mined. The most important of these thinner coals is the Osage, which is well up in the Missourian, or Upper Coal Measures, and statigraphically 2,000 feet above the Cherokee coal. The largest mines are in Osage County along the main line of the Santa Fe Railway. They were formerly the property of that corporation, but are now owned by the Mount Carmel Coal Company. The coal bed averages 20 to 22 inches in thickness, and is known to extend to the northeast as far as Brown County, though it is somewhat thinner in that direction. This seam yields about 6 per cent of the coal mined in Kansas. In Iowa a somewhat similar coal is mined in Adams, Page, and Taylor counties for local purposes. It occupies approximately the same stratigraphic position.

CHARACTER OF THE COAL.

The coals of the Western Interior field are exclusively bituminous. They are essentially steam coals, and are not generally used either for coking or gas-making purposes. In former years a small amount of coal from the Cherokee seam was made into coke and used in zinc smelting. At present practically none is so used. A fair grade of coke may be made from several of the coals by means of ovens of special construction, but in the absence of any large demand and in the presence of the necessity for thorough preliminary cleaning of the coal, no coke industry has so far been built up. The presence of normal coking coals to the east, south, and west of this field renders it doubtful whether a coking industry of any size ever will develop in this field.

The coals of this field are not usually adapted to gas making because of the large amount of sulphur and ash which they carry. In this particular the Mystic and Lafayette are much better than the ordinary coals of this field, and in a small way they have been used for gas making. The coals are mainly adapted for domestic and steaming purposes, and practically the entire output is devoted to these purposes.

ANALYSES.

The following tables of analyses are representative for the better-known coals. Many more analyses are available, but the ones selected are believed to be fairly representative.

Analyses of Western Interior coals.

State.	District.	Mine.	Fixed carbon.	Volatile combustible matter.	Moisture.	Ash.	Sulphur.	Fuel value.	Fuel ratio.
Iowa	Fort Dodge [a]	Collins No. 6	45.54	39.52	7.48	8.44	5.28	....	1.15
Do	....do	Craig Carmel	39.22	39.04	5.87	15.87	7.12	....	1.00+
Do	Boone [a]	Dalby	47.93	44.21	2.13	5.73	3.82	....	1.08
Do	Oskaloosa [b]	Keb	44.75	37.49	9.81	7.95	......	11.88 lbs. evap.	1.19
Do	Centerville [a]	Forbush	47.14	35.84	9.70	7.31	4.41	....	1.32
Missouri	Mendota [b]	Mendota Mining Co.	46.24	37.48	9.03	7.25	5.57	11.85 lbs. evap.	1.23
Do	Bevier [c]	K. & T. No. 43	52.50	36.66	4.39	6.45	1.80	....	1.43
Do	Lexington [d]	Graddy	42.19	29.01	9.24	15.18	4.38	10,849 B. T. U.	1.45
Do	Rich Hill [d]	Panama	48.68	30.91	4.44	11.74	4.23	12,307 B. T. U.	1.57
Kansas	Cherokee [d]	Fleming	56.32	28.70	3.08	7.96	3.94	12,756 B. T. U.	1.96
Do	Leavenworth [e]	State mine	33.91	33.52	6.58	15.99	1.19	....	1.01
Do	Osage [e]	....	41.13	40.03	7.19	11.65	......	5,322 cal	1.03
Do	....do [e]	Miller	......	......	......	......	......	5,476 cal	....

[a] Iowa Geol. Surv., Vol. II, p. 504, et seq.
[b] Lab. Chicago, Burlington and Quincy Railway, report for 1893.
[c] Analysis furnished by the company.
[d] St. Louis Sampling and Testing Works.
[e] Univ. Geol. Surv. Kansas, Vol. III, pp. 278, 294.

BOILER TESTS.

A much better indication of the value of the coal is afforded by steam-boiler tests. A few of these are published below:

Boiler tests of Iowa coals.

	I.	II.	III.
Grate surface ....square feet..	16	30	16
Duration of test..........................hours..	4	9	5.5
Average steam pressure..................pounds..	80	5	80
Temperature of feed water ....degrees..	72	60	56
Water evaporated, actual (first hour)....pounds..	9,781	24,781	22,397
Water evaporated from and at 212° .... do....	11,543	28,798	26,816
Coal fired ....do....	2,119	5,520	4,108
Ashes ....do....	367	856	516
Combustible.................................do....	1,752	4,664	3,592
Ashes ....per cent..	17.3	15.5	12.8
Water evaporated, per pound, actual.....pounds..	4.66	4.48	5.45
Water evaporated, per pound, combustible. do....	5.58	5.31	6.23
Water evaporated, per pound, from and at 212°, pounds..	5.44	5.21	6.52
Water evaporated, per pound, combustible, from and at 212°.........................pounds..	6.59	6.17	7.46
Rated horsepower	125	80	125
Horsepower developed	83	92	141
Coal consumed per square foot, grate service, pounds..	32	20	46
Draft..	.4	.5	.7
Temperature flue gases ....degrees..	700	600	1,000

I. Christy mine, slack coal, Kenney boiler 112, 2¾ by 10 inch flues, 1,255 square feet heating surface. Test by B. Knauer, Des Moines, October 26, 1900.

II. Bloomfield mine, slack coal, tubular boiler 52, 4-inch flues, 1,024 square feet heating surface. Test by B. Knauer, Des Moines, November 16, 1900.

III. Diamond Joe mine, mine run; Kenney boiler used in Test I. Test by B. Knauer, Des Moines, January 10, 1901.

It is to be noted that these tests were made on working boilers, and in two cases on slack coal. This is the lowest grade coal, but is the principal fuel for stationary boilers. In Des Moines it has a normal cost (delivered) of 80 cents per ton. It is regretted that there are no available records of similar tests on lump coal from this portion of the field.

Comparative evaporative tests of Missouri coals.

[Rich Hill lump, tested April 1, 1899; Warrensburg lump, tested April 3, 1899; Waverly lump, tested January 12, 1900; Lexington lump, tested January 15, 1900.]

	Rich Hill.	Warrensburg.	Waverly.	Lexington.
Duration of test .... hours..	8	8	9	9
Mean temperature of boiler room .... degrees F..	51	52	46	55.3
Mean temperature outside air .... do....	39	37	39.5	50
Condition of weather	Clear.	Snowing.	Clear.	Rain.
Mean steam pressure above atmosphere, by gage, pounds	65.4	64.1	66.7	65.5
Mean temperature of steam .... degrees F..	311.8	311	313.26	312.
Mean absolute steam pressure .... pounds..	80.1	78.8	81.4	80.2
Mean height of water level .... inches..	6½	6½	7¾	6¾
Mean of water entrained in steam .... per cent..	Dry.	Dry.	Dry.	Dry.
Mean temperature of feed water .... degrees F..	44	44	44	46
Water apparently evaporated .... pounds..	18,065	14,078	16,563	13,635
Equivalent evaporation to dry steam from and at 212° F .... pounds..	21,794	16,985	19,941	16,399
Equivalent evaporation per hour .... pounds..	2,724	2,122	2,216	1,822
Equivalent evaporation .... boiler horsepower..	78.9	61.5	64.2	52.8
Equivalent evaporation per hour per square foot of heating surface .... pounds..	3.73	2.9	3.04	2.5
Weight of coal used, plus coal equivalent of wood, pounds	3,186	2,693	3,220	2,797
Weight of ashes, clinkers, and coal which fell through grate .... pounds..	596	542	657	441
Waste .... per cent..	18.72	20.13	20.52	15.77
Unburned fuel which fell through grate ... per cent..	....	....	4.19	3.09
Clinkers in fuel .... do....	5.8	None.	7.49	7.85
Mean opening of damper (percentage of full opening) .... per cent..	100	100	100	100
Mean temperature of flue gases .... degrees F..	413	445	502.7	564
Mean pressure of draft in flue .... inches of water..	.5	.4	.33	.4
Mean thickness of fire .... inches..	5	5	5	5
Coal burned per hour per square foot of grate, pounds	22.7	19.2	15.8	15.35
Coal burned per hour per square foot of heating surface .... pounds..	.54	.46	.49	.43
Evaporation of water from and at 212° F., per pound of coal .... pounds..	6.84	6.27	6.23	5.86
Evaporation of water from and at 212° F., per pound of coal combustible .... pounds..	8.37	7.89	7.81	6.96
Fuel used (bituminous coal)	Lump.	Lump.	Lump.	Lump.
Chemical composition of coal, ultimate:				
Sulphur .... per cent..	4.32	4.74	6.25	2.28
Chemical composition of coal, proximate:				
Water .... per cent..	4.25	6.1	4.98	11.06
Volatile .... do....	34.09	34.28	39.02	38.94
Fixed carbon .... do....	40.84	37.13	35.95	37.1
Ash .... do....	16.5	17.75	20.05	12.9
Calorific power of coal, B. T. U., per pound, calculated .... by calorimeter..	11,610	10,836	10,642	10,191
Theoretical evaporative power from and at 212° F....	12.02	11.21	11.02	10.55
Total calorific power utilized, or efficiency .. per cent..	56.8	55.8	56.5	55.55
Capacity developed of boiler rating .... per cent..	131.5	102.5	107.0	88.

Description of boiler.—One return tubular steel boiler, 54-inch diameter, 16 feet long, with 36 4-inch flues. Heating surface: On shell, 166 square feet; of tubes, 564 square feet; total, 730 square feet. Plain setting, with "standard" rocking grates, 3 feet by 5 feet, giving 15 square feet of grate surface. Percentage of opening, 27½. Area of chimney's cross section, 4.25 square feet; height of stack, 72½ feet.

The above tests were made by the St. Louis Sampling and Testing Works for the Missouri Pacific coal companies, and are published through the courtesy of Mr. S. W. Farnham, engineer for those companies.

ENGINE RUNS.

The greater portion of the coal mined in the Western Interior field is used by the railways. Certain of the mines are worked exclusively for railway purposes. The coal when used for locomotive fuel is normally screened, but in the case of some of the coals mine run can be used. There are no records of systematic tests of the coal as a locomotive fuel. The notes kept by the various roads do not take into account variations in load and grade, and these are all important. The differences in the type of engine and fire box are not so important, since they are usually adapted to the particular coal used on the division to which the engine belongs. The following table gives the results in engine miles per ton for four of the larger railway systems of the West. The results cover all possible variations in grade and running conditions, and are based upon the use of practically all Western coals. So far as Western Interior coals are concerned, it can merely be stated that an examination of a considerable number of individual data indicates that specific tests of Western Interior coals would give results not greatly different from the general averages given below.

Result of engine runs.

	Engine miles per ton.
Missouri Pacific system	21.44
Santa Fe	21.66
Chicago and Northwestern	22.56
Wabash Railroad	19.8

DEVELOPMENT.

HISTORY.

Coal has been mined at various points in the Western Interior field since the earliest settlement of the area. The early mines were, however, small and were devoted only to supplying local demands. The building of railways into the territory gave mining a great impetus and each new line resulted in the opening of important mines. With the later increase in population and the beginning of manufacturing the output has steadily increased. The growth of the industry is excellently shown in the statistical tables in earlier pages of this report. These reflect merely the general development of the country, and aside from that coal mining in this field has no important history.

METHODS OF MINING.

As may readily be supposed, the irregular distribution of the workable coal in this field influences largely the methods and costs of both prospecting and opening. In the former work the difficulty of locating coal is increased, for much of the field has a covering of bowlder clay varying from 50 to 250 feet in thickness. The prospecting is nearly all done by drilling. Where the depth is less than 100 feet and there has been enough work done in the region to make the strata fairly well known, the common churn or percussion drill, driven by horse or steam power, is used. This work is cheap, the cost being from 25 to 75 cents per foot, but the results are uncertain and the extended use of this type of drill can not be recommended. The best work and all large contracts are done with the diamond core drill. This work costs about $1 a foot for average depths and conditions. Some of the larger companies own their drilling equipment and are thereby able to reduce a little the cost of prospecting.

The cost of prospecting in the Western Interior field is relatively high. The irregular distribution of the thick coal necessitates more drilling than is customary, and in general development work in this field necessitates a higher grade of skill, and the successful conduct of mining operations a wider knowledge, than in any of the competing coal fields. It would perhaps be fair to state that in prospecting in Iowa and Missouri one drill hole is on the average necessary to develop each 20 acres, whereas, in Illinois, for comparison, four drill holes on a section of land will in any but exceptional instances much more thoroughly locate the coal. In the Western Interior field coal companies usually find after a few preliminary holes that about one-third of the land under option is, by reason of thin coal or no coal, not worth further expenditure. The drilling is then concentrated on the remaining lands. In recent work in Iowa it required 40 drill holes to locate 1,000 acres of coal in one situation, 20 to develop 400 to 500 acres in another, and 27 to locate an equal amount in a third situation. In still another instance 20 drill holes, distributed over 5,000 acres, developed approximately 600 acres of workable coal. With such conditions it is manifestly impossible to give any trustworthy estimates of the probable total yield of the field. In addition to the influences already mentioned, distribution of the coal has been determined by erosion both in the present and in pre-Glacial time. This erosion seriously limits the amount of coal, but its effects can often be determined by a study of surface conditions, so that it does not add notably to the cost of prospecting.

The cost of mining is also seriously augmented by the irregular distribution of the thicker coal. In any mining operation the cost of dead work, including entry driving, timbering, track laying, cutting through bars, etc., forms a tax which must be assessed on the coal won in the productive work. In the field under discussion the amount of dead work is larger in proportion to the coal won than elsewhere. The irregular bottom requires considerable track work. In the thinner seams the roof must be brushed down. When pre-Glacial channels are cut the cost of timbering through them and the fixed charge for pumping become high. The irregular distribution of the thicker coal requires usually longer and more frequent entries to be driven to win a given amount of coal than elsewhere. It also makes it impracticable to use coal-mining machines in this field as exclusively as elsewhere. The fact, too, that the thick coal lies in limited and isolated basins makes it necessary to mine with small and relatively short-lived plants. It is accordingly impossible to realize the economy of production which comes with the installation of expensive plants with large capacity. In a general way it may be stated that the ordinary plant in this field has a rated daily capacity of approximately 500 tons and is expected to mine the coal under 160 to 300 acres of land. Such a mine has an ordinary life of 10 to 20 years. It is usually opened by means of double-compartment hoisting shafts 7 by 14 feet in the clear. Single mine cars carrying 1,200 to 2,200 pounds net are hoisted at a time. Mule haulage is most common, though tail ropes and continuous cables are not uncommon. There is very little electric haulage in this field. Recently there has been a tendency toward the opening of mines of larger capacity. There are now a number of 1,000-ton and a few 2,000-ton plants in operation. One of the best of the latter is owned by the Whitebreast Fuel Company of Illinois, and is located at Cleveland, Iowa.[a] It was the first plant in this field built with steel top works. Another excellent plant is that of the Western Coal Company, at Minden, Mo.[b] These two may be taken as typical of the larger new plants.

The mines of this field are not deep. A greater depth than 250 feet is exceptional. The deepest mines are at Leavenworth, Kans., and are 713 to 850 feet in depth.

Comparatively little of the coal is mined by long wall methods, the most of it being won by various forms of room-and-pillar workings. At present little undercutting or shearing is done, the coal being blasted off the solid. The coal is not cleaned, except by a little hand picking in the mine. It is sized ordinarily by means of stationary grizzlies, revolving trammels, or shaking screens. The latter are more common in the southern portion of the field and rare to the north. The sizes most commonly marketed are as follows:

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[a] See An Iowa coal mine: Eng. and Min. Jour., March 23, 1901, Vol. LXXI, pp. 361-362.

[b] This plant is described in the fourteenth annual report of the State coal mine inspector of Missouri, pp. 91-92.

Sizes and names of coal commonly marketed in Western Interior field.

<table>
<tr><td>$1\frac{3}{8}''$ and over.</td><td>$1\frac{3}{8}$–$\frac{7}{8}''$.</td><td>$\frac{7}{8}$–$\frac{1}{2}''$.</td><td>Through $\frac{1}{2}''$.</td></tr>
<tr><td>Lump.</td><td>Nut.</td><td>Pea.</td><td>Slack or steam.</td></tr>
<tr><td rowspan="2"></td><td></td><td colspan="2">Fancy steam.</td></tr>
<tr><td colspan="3">Extra steam.</td></tr>
<tr><td colspan="4">Mine run.</td></tr>
</table>

Big lump is over a 4-inch bar, and $1\frac{3}{8}$ to 4 inches is occasionally marketed as egg. In the shaker screens used in the Cherokee region lump coal passes over $1\frac{3}{4}$-inch perforations, nut over $\frac{3}{4}$-inch, and slack through the latter.

The proportion of lump to total product varies considerably from mine to mine. This variation is due both to changes in the character of the coal and to differences in the methods of mining and sizing. In general the lump ranges from 40 to 90 per cent. Probably the average percentage of lump is between 60 and 70 per cent.

CHARACTER OF LABOR.

The operators of this field are fortunate in the character and conditions of their labor. An unusually large percentage of the men working in the mines are English speaking, either Americans or English, Welsh, or Irish. In certain camps negro labor has been introduced as a result of strikes, but on the whole such camps are few. Of recent years Italians and Slavs have been coming into the region, and in certain districts, notably the Cherokee coal field of Kansas and Missouri and the Centerville or Appanoose district of Iowa and Missouri, they form a majority of the workmen. The different classes of labor have the same characteristics here that they have elsewhere. The Anglo-Saxons are the best miners. They have a better comprehension of the work to be done, and are quicker and more intelligent in the handling of machinery. Indeed, practically all the machinery about the mines is handled by them, and almost all the bosses are chosen from their ranks. As hand laborers they undercut the coal, shear it, and blast so as to produce a large percentage of lump. With, or perhaps as a result of, the gradual introduction of other classes of labor the coal has less and less undercut, and the practice of shooting from the solid has become more common. The result is that poorer grade coal is now marketed than formerly. In such mining, where quantity and not quality of work counts, the higher priced laborer is at a disadvantage; a result for which he is in some sense to blame, since the old miners have been only too ready to second the efforts of the newcomers to force payments on a mine-run basis.

The negro in the mines is hard working when properly supervised, but is not intelligent in his individual efforts. He is not a steady workman, and is given to many holidays. He spends his money freely where he can get credit, so that where there is a company store the negroes form a profitable class of labor. The Italians working in this field are mainly from southern Italy. They are hard, faithful workers, but usually know little about mining. They are very economical, so that they add little to the profits of a company store. Their reputation for quarrelsomeness seems on the whole undeserved, they being as quiet and peaceable as any class of workingmen in the district, when managed by one who can talk with them. The bosses in this field very rarely attempt to learn the Italian language, and the limited knowledge of English which the Italians themselves have is a fruitful source of friction. The Slavs who have come into the field are as yet few in number, and are like the Italians in general disposition, though usually of much better physical build.

In the relations of the men and the operators to labor unions the field is particularly interesting. Ten years ago the miners in this coal field were practically unorganized. From time to time they have become better organized, until now in the northern portion of the field they are supreme.

In Iowa the miners belong to the United States Mine Workers (District 13). They are so completely in control of the situation that the operators have in turn formed the Iowa Coal Operators' Association, and all matters relating to labor are regulated by an annual contract between the two organizations. In Missouri and Kansas there is no organization of the operators, and the men are only partly organized. Four of the strongest companies operating in the two States, after a long and desperate fight, defeated the union and now give it no recognition. In these States, accordingly, union and nonunion mines run side by side. There is little if any difference in the wages paid at the union and the nonunion mines. In fact the union scale of wages prevails throughout the coal field. When the operators have objected to the recognition of the union, the objection has seemed to be not to the scale of wages but to the restrictions on mining which the union has undertaken to enforce in other ways. For example, there has been a persistent attempt to force payments to a mine-run basis. The objections to this lie in the fact that comparatively little of the output can be sold as mine run. In that form it is not good enough for domestic and locomotive use and is too expensive for stationary steam plants. Unless the pay of the men depends to some extent on the amount of lump coal which they produce, they do not use the proper care in either mining or loading. As a result, if the operator pays his men on a mine-run basis and then screens his coal for his customers, he runs behind. This is true of a large majority of the coals mined in this field, though not of those which can be profitably sold unscreened. The union has also worked to minimize the advantage accruing to an operator from the introduction of mining machines, taking the ground that the better condition in which his coal reached the top was sufficient advantage and that to allow him also an advantage in cost would only lead to cutting of prices on pick mining. In Iowa, in particular, where even up to the present the miners are much better organized than the operators, the men have been successful in holding up prices for labor notwithstanding a decline in selling value of output, and at the same time have won shorter hours and substantial union benefits, while the quality of the work done has steadily diminished. All this has thrown a heavy burden on the operators, and to-day it is believed that Iowa miners are relatively better paid than are those of any coal-producing State with which Iowa operators have to compete. This has prevented a more rapid increase of output, and, with the lower average quality of the coal as compared with that of competing fields, has placed the Iowa operators at a marked disadvantage. The close union of the men has undoubtedly, however, been good for them in many particulars and good for the trade as a whole in others. It has been the most effective agency in doing away with the old-time abuses of the company store. That institution as now run affords a legitimate profit to the operator by reason of the large trade which naturally falls to it from the ability to extend credit. At the same time, it is a common convenience and help to the miner. The prices charged compare favorably with those charged in any similar store appealing to the general trade, and at the same time the quality and the variety of goods are usually far beyond those which under other circumstances would be open to the miners' choice. The union has also done away with the abuses of the renting system, and rents paid are usually just and proportionate to the accommodation offered. From the standpoint of the trade in general the dominance of the union has been beneficial chiefly in steadying the trade and greatly decreasing unfair and unequal competition between district and district and mine and mine. A secondary advantage which is just beginning to be realized is the bringing of the operators closer together. With mutual acquaintance is coming cooperation in certain ways in the place of competition, and with the thorough organization of both men and operators it seems probable that miners' strikes at least will disappear and that difficulties and disagreements will be more quickly and easily adjusted.

In Kansas and Missouri things are not so well adjusted. As already stated, many of the most powerful companies refuse to deal with the union at all. They are in an independent position as regards their time and methods of working, and they feel that the money spent in fighting a long strike brings good returns in this fact. In the two States as a whole, however, the conditions are bad, in that they are quite unequal from point to point, and that the competition of mine with mine is much more unequal than farther north. It is doubtful whether the results have been altogether beneficial to the general public. The prevailing conditions have undoubtedly raised the price of coal above what it would otherwise have been, and whether or not there have been corresponding benefits to the public at large is open to question.

COST OF MINING.

It is very difficult to get a reliable estimate of the average cost of mining coal in a field as large as this and one in which the natural and commercial conditions are so varied. It is believed worth while, none the less, to present the following estimate. These are based upon returns covering the production of nearly 5,000,000 tons in 1899. The result is probably as nearly an average as can be readily arrived at:

Cost of mining per ton (2,000 pounds) in Western Interior coal field.

Amount paid to miner, from which he pays for powder, oil, and tool sharpening, in all about 10 cents	$0.80
Amount paid for labor aside from miners, including drivers, cagers, trappers, pit boss, superintendents, clerks, etc	.13
Timber, track, and underground supplies	.05
Repairs and sinking fund	.06
Royalties	.05
Sales agents or commissions	.10
Total cost	1.20

These items vary in different parts of the field and at different times. Royalties, for example, range from 4 to 20 cents per ton, but probably the bulk of the coal mined on royalties costs from 4½ to 6 cents. When there is no royalty there must be a corresponding charge for interest and sinking fund covering investment in lands. The repairs and sinking fund figured above are to cover the ordinary plant and a moderate amount of dead work on development. The high labor cost of coal is at once apparent. Indeed, the labor and transportation costs are the main elements in the price of coal. The selling price and labor cost for the years 1890 and 1899, as shown by the report of the Iowa State mine inspectors, are instructive and are given below.

Selling price, labor cost, and amount paid miners per ton in 1890 and 1899.

Year.	Selling price.	Total labor cost.	Amount paid miners.
1890	$1.42	$1.17	$0.90
1899	1.29	.93	.80
Decrease per ton	.13	.14	.10

According to these figures the labor cost per ton has decreased almost exactly the amount that the selling price at the mine has gone down. The amount paid to the miner, however, has gone down only 10 cents per ton; the decrease in labor cost has come from economies in the general staff of the company and in the use and pay of company men. It is to be regretted that figures are not at hand for the years 1899 to 1901, since prices in that period rose and a comparison would be very instructive.

Tho profit in mining a ton of coal is extremely variable. This is particularly true in the Western Interior field, where the manufacturing interests are relatively unimportant and the trade is largely dependent on climatic and crop conditions. It is, accordingly, very unequal, and at times the capacity of the mines is taxed, while at other times coal must be sold at an actual loss to avoid a complete shut down. In a general way it may be stated that under normal conditions coal sells for 10 to 15 cents above operating cost per ton, and that in the busy season under favorable circumstances it sells at a profit of 25 cents per ton in large quantities. This profit must, however, carry the loss of other periods and any unusual expense, such as a big squeeze in the mine, an uninsured fire, a strike, the sinking of any unusually expensive or difficult shaft, etc. When these things are taken into account, it appears that the profits in mining coal are not larger than are fair to all interests concerned. There are good profits under favorable conditions and good management. Occasionally the profit is quite handsome, but the business involves a considerable investment and necessitates careful management.

PROSPECTIVE DEVELOPMENT.

There is no apparent reason for anticipating any marked change in the steady development which this field has for some years experienced. As the population increases and the manufacturing industries are built up, the present increasing demand for coal will continue. The railways will, in time, as their general business increases and their tracks and equipment are improved, be able to grant better freight rates, and this will result in extending the market for the local coals. Mining will gradually come to be carried on farther to the west in this field. This will mean deeper mines and thinner coal, but, so far as present experience goes, more regular beds. The Leavenworth mines are an instance in point, and are a prophecy of what may ultimately be expected to develop at a number of places now west of the scene of active mining. This development may be expected to come gradually, and in the meanwhile an increasing number of new and larger mines are being opened as old ones are worked out. At present, plans are under way for a considerable number of such plants.

STATISTICS OF PRODUCTION.

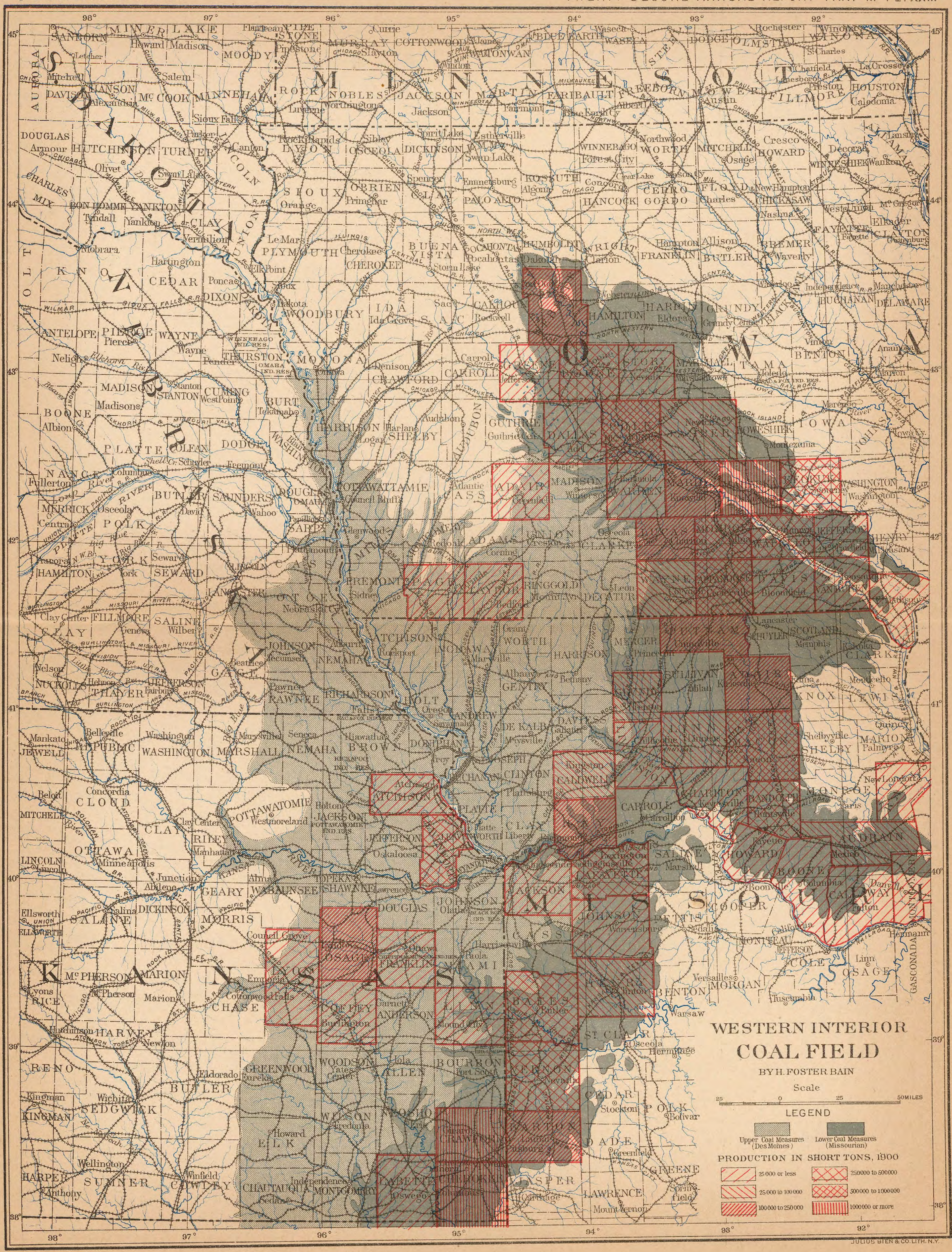
Relation of production to capacity of mines for the Western Interior coal field in 1900.

State.	Number counties producing coal.	Number commercial mines.	Production, 1900.	Estimated capacity of mines, 1900.	Ratio of production to capacity.	Per cent of mines reporting prospective increase of capacity.
			Short tons.	*Short tons.*		
Iowa	24	251	5,202,939	7,797,380	67	43
Missouri	24	174	3,540,103	4,635,753	76	45
Nebraska	....	....	0	....	....	....
Kansas	13	139	4,467,870	6,226,059	72	43

Production and distribution of product of the Western Interior coal field for 1900.

Subdivision of field.	Production.	Value at mines.	Average value per ton.	Railroad fuel.	
				Quantity.	Per cent.
	Short tons.			*Short tons.*	
Iowa	5,202,939	$7,155,341	$1.38	1,768,999	34
Missouri	3,540,103	4,280,328	1.21	1,274,438	36
Nebraska	0	....	....	....	....
Kansas	4,467,870	5,454,691	1.22	1,295,682	29
Total for field	13,210,912	16,890,360	1.27	4,339,119	33

Subdivision of field.	Steamboat fuel.		Manufacturing fuel.		Domestic fuel.		Made into coke.	
	Quantity.	Per cent.	Quantity.	Per cent.	Quantity.	Per cent.	Quantity.	Per cent.
	Short tons.		*Short tons.*		*Short tons.*		*Short tons.*	
Iowa	0	0	936,529	18	2,497,411	48	0	0
Missouri	0	0	920,426	26	1,345,239	38	0	0
Nebraska	0	0	....	....	....	....	0	0
Kansas	0	0	1,429,719	32	1,742,469	39	0	0
Total for field	0	0	3,286,674	25	5,585,119	42	0	0


WESTERN INTERIOR
COAL FIELD
BY H. FOSTER BAIN
Scale
25 0 25 50 MILES
LEGEND
Upper Coal Measures (Des Moines)
Lower Coal Measures (Missourian)
PRODUCTION IN SHORT TONS, 1900
25 000 or less
25 000 to 100 000
100 000 to 250 000
250000 to 500000
500000 to 1000000
1000000 or more
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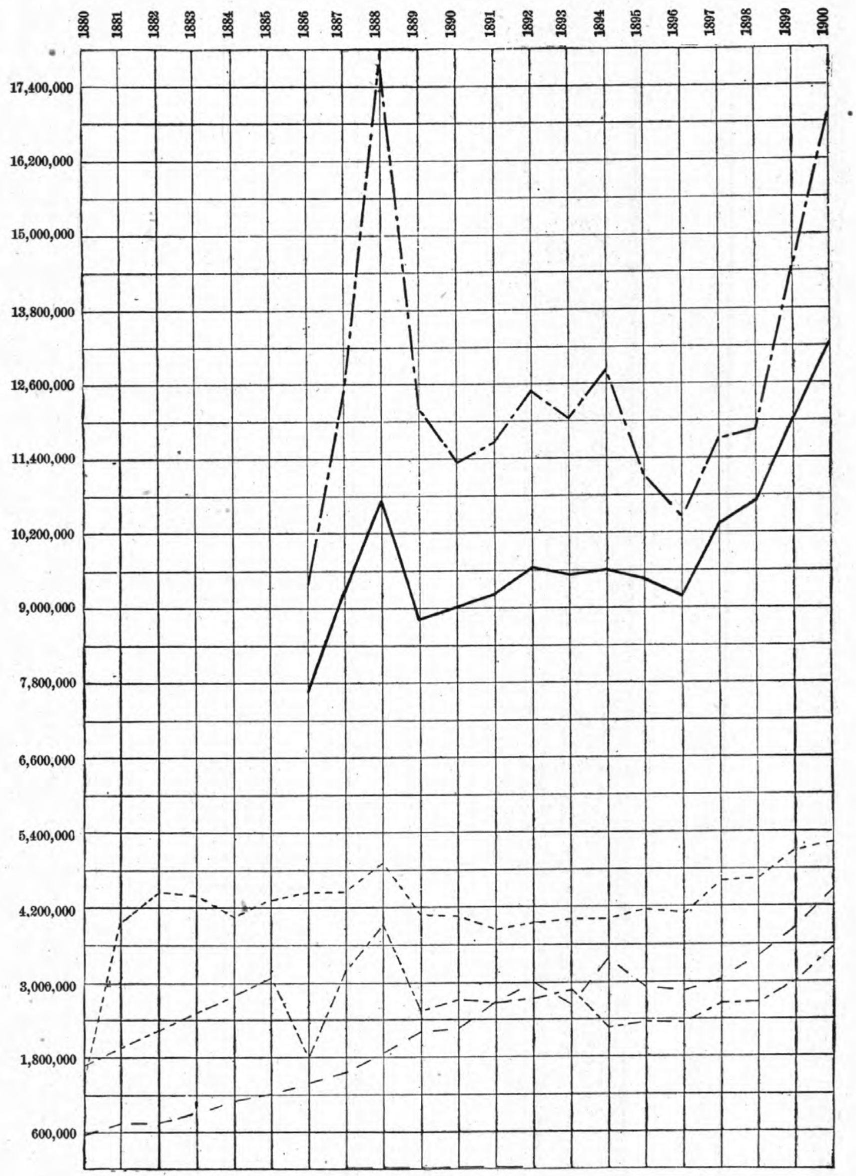


FIG. 33.—Production and value of coal in the Western Interior coal field from 1880 to 1900.

------ Iowa. ———— Nebraska. —·—·— Missouri. — — — Kansas. ▬▬▬ Total production. ——-—— Total value.

Scale {600,000 tons to the square.
{$600,000 to the square.

Development of the Western Interior coal field by decennial periods.

State.	1880. Production.	1880. Value.	1880. Average price per ton.	1890. Production.	1890. Value.	1890. Average price per ton.
	Short tons.			*Short tons.*		
Iowa	1, 461, 166	$2, 507, 453	$1. 72	4, 021, 739	$4, 995, 739	$1. 24
Missouri	884, 304	1, 464, 425	1. 66	2, 735, 221	3, 382, 858	1. 23
Nebraska	200	750	3. 25	1, 500	4, 500	3. 00
Kansas	771, 442	1, 517, 444	1. 97	2, 259, 922	2, 947, 517	1. 30

State.	Increase of 1890 over 1880. Product.	Per cent.	Value.	Per cent.
	Short tons.			
Iowa	2, 341, 739	160	$2, 488, 286	99
Missouri	1, 850, 917	209	1, 918, 433	131
Nebraska	1, 300	650	3, 750	500
Kansas	1, 488, 480	193	1, 430, 073	94

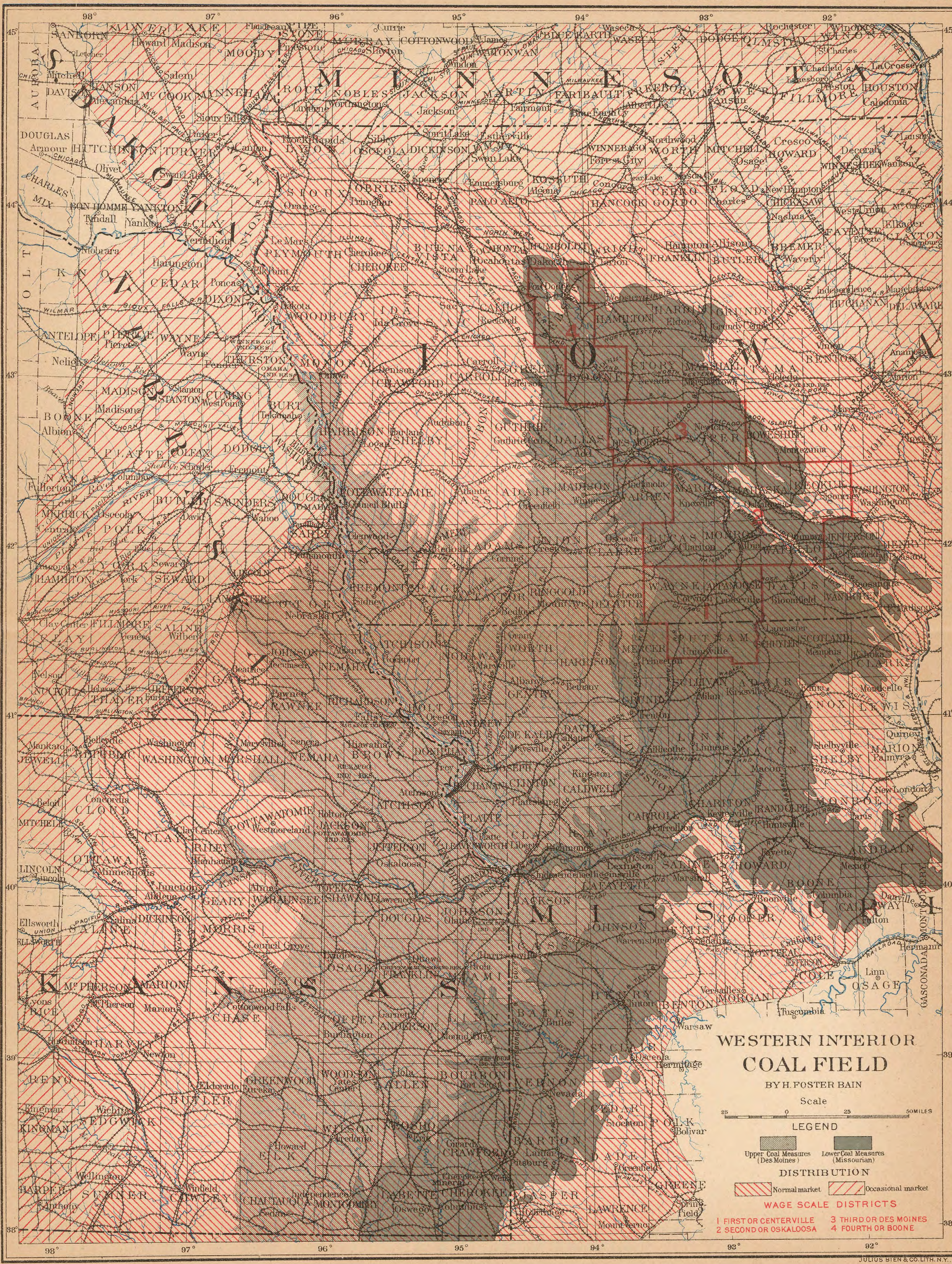
State	1900. Production.	1900. Value.	1900. Average price per ton.	Increase of 1900 over 1890. Product.	Per cent.	Value.	Per cent.
	Short tons.			*Short tons.*			
Iowa	5, 202, 939	$7, 155, 341	$1. 38	1, 181, 200	29	$2, 159, 602	43
Missouri	3, 540, 103	4, 280, 328	1. 21	804, 882	29	897, 470	27
Nebraska	0	0	0	[a]1, 500	[a]100	[a]4, 500	[a]100
Kansas	4, 467, 870	5, 454, 691	1. 22	2, 209, 948	98	2, 707, 174	98

[a] Decrease.

DISTRIBUTION.

LOCATION AND CHARACTER OF MARKETS.

The area which constitutes the market for the coal of the Western Interior field is shown on Pl. XXIV. The inner area is that within which it is the commanding coal—i. e., where under normal conditions the bulk of the trade is supplied by the coals of this field. The outer area is that within which it still sells to a considerable extent, but in competition with other coals which are favored either by location, quality, or freight rates. The most striking facts brought out by this map are that the coal is largely consumed locally, and that where it is



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marketed outside the limits of the coal field itself it passes north and west. To the south and southwest it can not compete with the coal of the Southwestern field. It moves east to only a very limited extent and under peculiarly favorable circumstances, since it is brought into contact at once with the better coals of the Central and Appalachian fields. Occasionally it is sold as far east as the Mississippi River. For example, the local market at Keokuk, Iowa, has for some years absorbed a considerable amount of the Centerville coal. This is due to the fact that the latter coal is, for domestic use, considerably better than the usual coal of this field and that the Keokuk and Western Railroad, now a part of the Burlington system, affords a direct route under local control. Cedar Rapids, again, takes considerable coal from Keokuk County, Iowa; and the towns far to the northwest, along the Burlington, Cedar Rapids and Northern Railway, afforded an important market for What Cheer coal. This is due to close relations existing between the road and the mines and the absence of competing coal on this railway system.

In earlier years the coal of Iowa, Missouri, and Kansas supplied a greater portion of the territory to the west. With the opening up of Colorado and Wyoming coal mines some of this territory was lost. The Western coals were, in many instances at least, better in quality. The mines were located in a less densely populated area, and accordingly had less of a local market. They were opened usually by companies closely affiliated with railway lines, and the coals therefore became vigorous contestants for trade. They drove the Western Interior coals back to the East at the same time that cheaper lake navigation gave the Appalachian coals an important advantage to the North, and better railway facilities brought the Illinois coals into the same territory. For a series of years the Western Interior coals lost trade territory, though local demand increased steadily and the output of the mines grew. Recently there has been the beginning of a change. The Newcastle, Wyo., coal, which used to come into the Sioux City and Omaha markets, is now absorbed nearer the mines. Other Western coals are not so aggressive, and the Western Interior coals are gaining a substantial portion of the increased trade of eastern Nebraska and middle Kansas. Rock Springs coal, for example, does not now come east of Hutchinson, Kans., in quantity, though it is sold to some extent in Omaha. The Omaha market also receives Kansas, Missouri, Iowa, and Illinois coals in quantity, with limited amounts of the high-grade western Arkansas coals for smelting purposes. The Kansas City market is dominated by the Cherokee coal, though it is an open market to many of the mines of the Western Interior and Southwestern fields. The St. Louis market is open to Western Interior coals only in times of strikes or other difficulties in the central field.

USES OF THE COAL.

Approximately half the coal mined in this field is used by the railways, principally for locomotive fuel. The amount of coal used by the railways is very large. For example, the Chicago and Northwestern in the year ending May 31, 1900, used 2,077,374 tons, costing $3,363,251.82. The Santa Fe system used 1,800,247 tons, costing $3,024,416.96, a ton of fuel oil being estimated as the equivalent of 1¼ tons of coal. The Chicago, Milwaukee and St. Paul in 1900 spent $2,596,251.80 for fuel. All these railways and others crossing the Western Interior field obtain an important portion of their supply from the mines in it. They are by far the largest customers which the mines have, and the relation of the road to the tributary mines is usually close.

The second largest market for the coal of this field is domestic. The region is devoted to agriculture, and manufacturing is but slightly developed. Probably 30 to 40 per cent of the coal is burned in the homes for heating and cooking. From 10 to 20 per cent is used in manufacturing. No coal is exported, nor is the coal of this field likely to reach any foreign market.

FREIGHT RATES.

The two factors which limit the market for the Western Interior coals are, first, the lower average quality of the coal as compared with the competing coals; and, second, the higher average freight rate as compared with that charged on Eastern coals. Coal is the largest single item of freight on most railways. Even the so-called granger roads of the Western States transport more coal than any other single commodity. The percentage of coal to total freight tonnage carried by a few railways of both the East and the West is given below, the figures being taken in each case from the official reports of the management to the stockholders. The figures are for the year 1899, but as the fiscal year on the various roads ends differently they are not for exactly the same period:

Proportion of coal traffic of various railways to total freight.

	Per cent.
Missouri Pacific system	17.8
Wabash Railroad	24.6
Chicago, Milwaukee and St. Paul	10.9
Santa Fe system	23.5
Baltimore and Ohio Southwestern	24.18
Baltimore and Ohio system	42.19
Chesapeake and Ohio	42
Lehigh Valley	52

Since the main earnings of a railway are usually from the freight traffic, it is seen that the transportation of coal is one of the most important sources of revenue. Coal is, however, a low-class freight, and takes a relatively low rate. There are substantial reasons for this. For example, in case of wreck there is very little, if any, loss, since the coal spilled is gathered up and used by the road itself. Again, the clerical work in handling coal traffic is light. There is only one waybill per car, and the coal is gathered up at relatively few points. Switching charges are light, as a whole string of cars are set in at once and are usually taken out at one time. The cars used in the transportation of coal are cheap. Ordinarily on Western roads coal is shipped in old cars which have already paid for themselves. In much of the traffic, particularly in the case of the granger roads, coal is return freight, and is loaded into box, or even cattle cars, which would otherwise run empty. Coal is also a relatively steady traffic. While in the Western Interior field the bulk of the coal is mined and shipped in the winter months, there are big shipments all the year round; and even the so-called shipping season does not compare in shortness with that of other commodities, such as fruits, grains, agricultural implements, etc.

While all these factors tend to reduce the cost, and therefore the charge, for transporting coal, they apply unequally in different fields. The cost of transporting coal in and from the Western Interior coal field is relatively higher than are costs to the east. The effect of this is seen in the following table, in which the transportation rates from this, as compared with other fields, to points within the area to the north and west within which there is competitive selling are compared. The approximate short-line distance in each case is also given below:

Distances to markets and freight rates.

From—	To—									
	Grand Island, Nebr.		Hastings, Nebr.		Yankton, S. Dak.		Sioux Falls, S. Dak.		Sioux City, Iowa.	
	Distance.	Rate.	Distance.	Rate.	Distance.	Rate.	Distance.	Rate.	Distance.	Rate.
	Miles.		*Miles.*		*Miles.*		*Miles.*		*Miles.*	
St. Louis, Mo	570	$3.15	570	$3.15	....	....	....	....	....	....
Chicago, Ill	659	3.60	659	3.60	578	$3.25	559	$2.66	517	....
Peoria, Ill	548	3.37	548	3.37	611	3.25	641	2.66	550	$2.66
Spring Valley, Ill	....	....	....	....	577	3.25	543	2.41	525	2.41
Iowa mines	314	2.35	314	2.35	196—	2.50	275	[a]2.00	135	{ [b]1.10 [c]1.28
Milwaukee, Wis	....	....	....	....	623	3.00	511	2.41	561	2.41

[a] Appanoose mines. [b] Fort Dodge mines. [c] Iowa mines in general.

Distances to markets and freight rates—Continued.

From—	To— Watertown, S. Dak.		Lincoln, Nebr.		Omaha, Nebr.		Minneapolis, Minn.		Mankato, Minn.		Mason City, Iowa.	
	Distance.	Rate.	Distance.	Rate.	Distance.	Rate.	Distance.	Rate.	Distance.	Rate.	Distance.	Rate.
	Miles.		*Miles.*		*Miles.*		*Miles.*		*Miles.*		*Miles.*	
St. Louis, Mo	......	......	478	$1.95	439	$1.80	......	......	......	......	......	......
Chicago, Ill	518	$3.15	567	2.40	500	2.25	421	$1.65	431	$1.60	356	$2.00
Peoria, Ill	569	3.15	456	2.17	489	2.02	501	1.65	......	......	333	1.85
Spring Valley, Ill	626	3.15	......	......	500	2.00	507	1.65	......	......	383	1.99
Iowa mines	276	2.75	222	1.30	155 to 219	[a]1.15 [b]2.00	333	[b]1.75 [c]1.65	163	1.60	144	1.42½
Milwaukee, Wis	......	......	......	......	515	2.25	420	1.65	471	1.90	312	1.90

[a] Mine run, main line C., B. & Q. [b] Iowa mines in general. [c] Appanoose mines.

A comparison of the figures will show that the rate per ton mile is considerably higher on coal shipped within this field than on coal shipped at lake ports or within the Central field. If detailed figures were available covering the rates on coal originating still farther east even more striking differences would be apparent. There are substantial reasons why this should be so. The Eastern roads run through a much more densely populated country and accordingly have a larger volume of traffic. For example, the average tonnage per train on the Chicago and Northwestern Railway, an exclusively prairie road, is 208 tons. The Chesapeake and Ohio, a mountain road not running through many large cities, has a corresponding tonnage of 488 tons. On the Pennsylvania the tonnage is 470. Again, the Western roads are not so well built as Eastern roads. This increases the cost of operation and at the same time makes necessary large annual charges for betterments. Reductions of curvature and grade, ballasting, relaying of rails and similar improvements are being carried on by most Western roads on an enormous scale and much remains to be done. In the East, this work is largely done and the roads are now enjoying the benefits of increased earnings. Coal itself is cheaper in the East, and as fuel is one of the important elements of expense in the operation of railways this has its influence. In the table below are given the total cost of operation per train mile and the fuel cost for six roads, three Western, two Eastern, and one, the Wabash, belonging in part with each group, but drawing its coal supply mainly from Illinois.

Cost per train mile.

	Total.	Fuel cost.
	Cents.	*Cents.*
Chicago and Northwestern	20.63	7.48
Santa Fe	22.08	7.64
Missouri Pacific	21.50	6.56
Wabash	17.23	4.88
Chesapeake and Ohio	15.16	4.39
Norfolk and Western	13.1	3.95

Freight rates in general are accordingly cheaper in the East than in the West. On Eastern roads the usual revenue per ton mile runs between 0.4 and 0.5 cent. On Western roads it is 0.8 to 1 cent on the larger systems. There is apparently more difference between coal rates in the East and West than between rates in general. It is a well-known fact that coal mined in West Virginia, for example, can be shipped 1,000 miles west at a much lower rate than can coal originating in the Western Interior field. Appalachian coal accordingly comes into the Western markets and competes unfairly for the trade entirely aside from the competition in quality. In the same way Illinois coal travels into and through the Western Interior coal field and competes for trade in the debatable ground to the west. While there may be, and doubtless are, substantial reasons why freight rates in general and coal rates in particular in the East are lower than in the West, there seems to be no good reason why coal shipped in Illinois and at lake ports should be transported to South Dakota and Nebraska at any greatly lower rates per ton mile than is charged by the same railway for hauling coal shipped in Iowa, Missouri, or Kansas. There is the legitimate decrease in rate with increased length of haul, but rates now prevailing show more than this difference. The table of coal rates given shows that Illinois coal and lake coal is favored by the roads at the expense of Iowa coal. There are also many striking anomalies in the rates cited.

It is also a question whether the lower coal rates prevailing in the East are not made at the expense of other traffic, at least in enough instances to affect the general situation and to unfairly tax the Western coal producer. The differences between Eastern and Western rates are, however, largely temporary and will disappear as the track and equipment of Western roads is improved and their volume of business increases. This in turn will probably result in an extension of the market to the north and west for Western Interior coals. Since, however, they are largely domestic and steaming coals they will probably always be at some disadvantage. The large metallurgical and manufacturing plants of the East, for example, require a better coal. They assure a steady market, and so decrease costs both of mining and of handling coals. The Eastern roads use 40 to 50 ton cars, built especially for the traffic. Much of the Western coal goes to local dealers, who prefer small cars. Accordingly, the standard carload of Western coal is from 20 to 25 tons. Larger cars are beginning to be introduced for the use of the roads themselves and other large users of coal.

ROUTES TO MARKET.

The routes followed by the Western Interior coals to their markets are sufficiently indicated by the maps accompanying this report (Pls. XXII, XXIII, and XXIV). In general, all railways passing from the coal field to the north and west carry considerable amounts of coal. The closeness and the nature of the relations between the road and the mining interests along it influence the volume of the coal traffic in each case. In the northern portion of the field the Chicago and Northwestern, Rock Island, Iowa Central, and Burlington roads have heavy coal traffic. Farther south the Missouri Pacific, the Missouri, Kansas and Texas, and the Santa Fe are the principal coal-carrying roads. Those railways which are direct owners of mines, or along which mines are operated by closely affiliated companies, naturally carry the largest amounts of coal. In general, however, the most coal is carried by the largest systems—those which on the one hand reach the greatest number of mines, and on the other the greatest number of distributing points. No single road or group of roads controls either traffic or production, and the problems of the independent producer versus the company mine have not yet come to complicate the situation.

THE SOUTHWESTERN COAL FIELD

BY

JOSEPH A. TAFF

CONTENTS.

ILLUSTRATIONS.

THE SOUTHWESTERN COAL FIELD.

By Joseph A. Taff.

GEOGRAPHIC RELATIONS.

LOCATION OF THE FIELD.

The Southwestern coal field connects with the Western Interior coal field at the Kansas–Indian Territory line. The line of division between the two fields is arbitrary and is made merely for convenience in treatment. That part of the Southwestern field which lies in southern Indian Territory and Arkansas is being extensively developed, and is, therefore, fairly well known. The northern part, adjoining Kansas, is entirely undeveloped in a commercial way. Little is known, therefore, of the number, thickness, and quality of its coals.

SUBDIVISIONS OF THE FIELD.

The Southwestern coal field includes the three districts of Indian Territory, Arkansas, and north Texas. The Indian Territory and north Texas districts are separated by the geographic and geologic barrier, the Arbuckle Mountains. The Indian Territory and Arkansas districts are directly connected, but are considered separately because of the different conditions under which the coals have been developed and because of differences in the amount of available geologic information.

The location of these three districts is shown on the map of the coal field (Pl. XXV). The districts will be considered in the order named above.

INDIAN TERRITORY COAL FIELD.

LOCATION AND BOUNDARIES.

The Indian Territory coal field is directly connected with the Kansas coal field on the north and the Arkansas coal field on the east. It includes parts of the territory occupied by the Five Civilized Tribes of the Indian Territory and a small part of eastern Oklahoma. It occupies, generally speaking, the western half of the Cherokee, the whole of the Creek, the northeast corner of the Chickasaw, and the northern third of the Choctaw Nation. The field has an area of approximately 20,000 square miles.

The Indian Territory coal field is geologically bounded on the north by the Coal Measure rocks of Kansas, of which it is a continuation. On the east, in the western slopes of the Ozark Mountain uplift, it is limited by the underlying Carboniferous rocks, in the Arkansas River Valley by the Coal Measure rocks of the Arkansas field, and in the Ouachita Mountain uplift by older Carboniferous rocks. On the south it is limited by the Carboniferous rocks of the Ouachita and Arbuckle mountains, and by the Cretaceous rocks which overlap between the two mountain uplifts in the vicinity of Atoka. On the west it is limited by outcrops of older Carboniferous rocks of the Arbuckle Mountains and by the later Carboniferous of the plains of western Indian Territory and Oklahoma.

The extreme western part of the field, lying immediately north of the Arbuckle Mountains, has not been surveyed and the geographic or geologic limits are not known. Coal-bearing rocks in the southern part of the field are not known to occur farther west than the region of Stonewall, Chickasaw Nation. On the Gulf, Colorado and Santa Fe Railroad, north of the Arbuckle Mountains, the Red Beds above the Coal Measure rocks approach near the mountain, and opposite the west end of these mountains they overlap and conceal these strata.

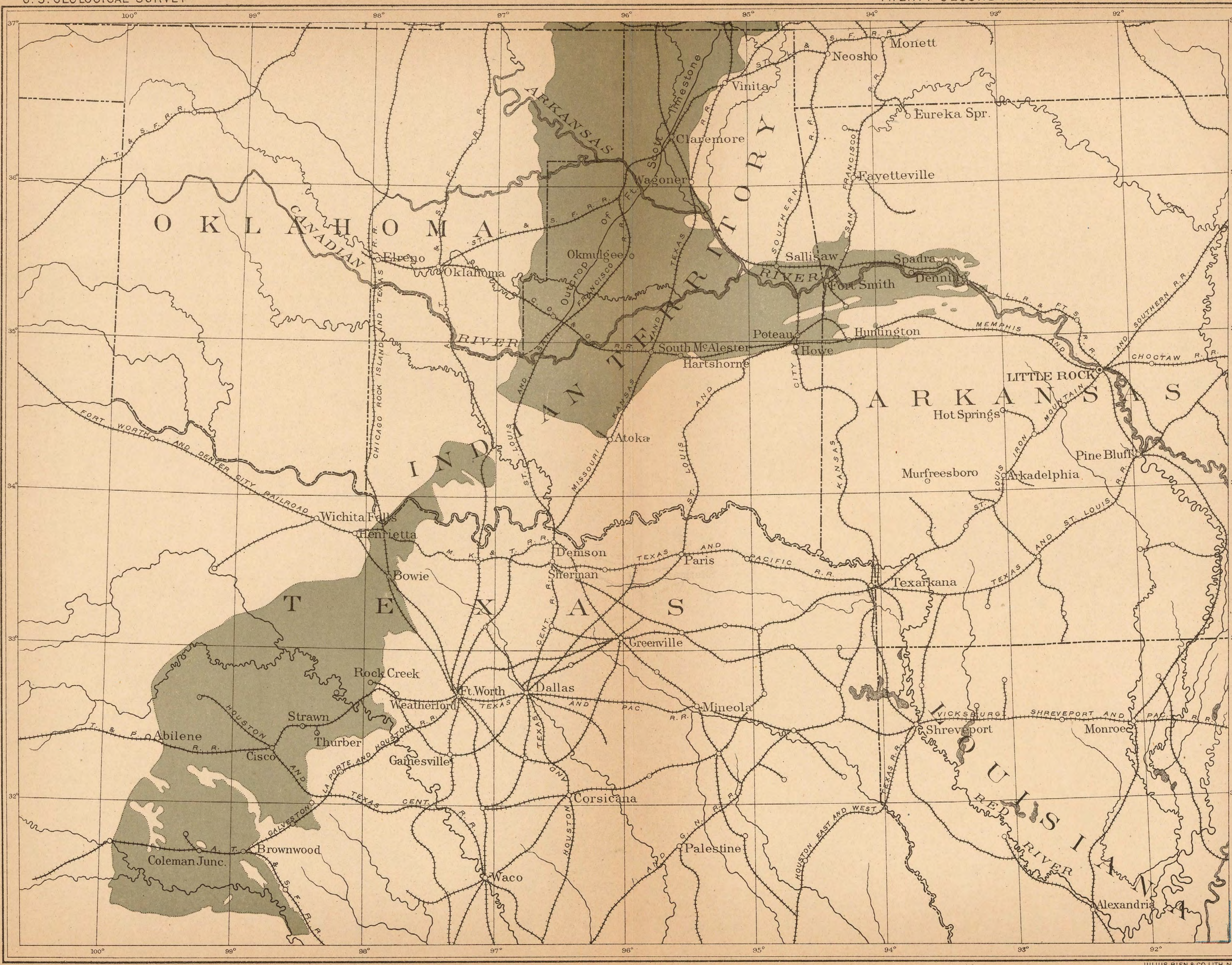
The geologic boundaries of the Indian Territory coal field north of the Arkansas River are taken in part from the work of Dr. N. F. Drake.[a] Later and more detailed work by the United States Geological Survey in the southern and western parts has made important additions to the results obtained by Dr. Drake.

AGE OF THE COAL.

The coal-bearing rocks of the Indian Territory coal field all belong to the Coal Measures of the Carboniferous. They were classified by Dr. Drake, who, apparently for reasons of convenience, placed the top of the Lower Coal Measures at the base of the lowest coal bed, which is known in the southern part of the field as the Hartshorne or Grady coal. Since Dr. Drake's preliminary survey it has been determined by paleontologic evidence that the lowest coal beds known in this field are most probably in the upper part of the Lower Coal Measures, while the highest coal is in the Upper Coal Measures, and below the top as compared with sections of the Coal Measures in the Appalachian and Western Interior coal fields.

In the southern part of this field, from the Hartshorne coal downward, there is a great thickness of strata which belong to the Pennsylvanian (Upper Carboniferous) series. They contain very few fossils, and no coal so far as known.

[a] A geological reconnaissance of the coal fields of the Indian Territory: Proc. Am. Philos. Soc., Vol. XXXVI, 1898, pp. 327–419.



SOUTHWESTERN COAL FIELDS

Scale

25 0 25 50 75 100 MILES

GENERAL STRATIGRAPHY.

ROCKS BELOW THE COAL.

In the southern part of the field, below the lowest coal bed, the Hartshorne or Grady coal, there is a group of rocks of great thickness, composed of shale and sandy strata, with a long lentil of limestone in the lower part. The limestone lentil has a maximum thickness of 400 feet, and extends nearly across the Choctaw Nation. At the southwest side of the coal field this group of rocks is exposed down to the Mississippian, revealing over 3,000 feet of strata. In the southeast corner of the field, in the valley of Poteau River, it has a thickness of more than 7,000 feet. In Backbone Mountain, 15 miles south of Fort Smith, probably less than half of it is exposed in a faulted uplift. In the south side of the Boston Mountains, north of the Arkansas River, the thickness is estimated at 2,000 feet. Opposite Fort Gibson, still farther north, it is 250 feet, and thence northward there is a gradual diminution of thickness until only a few feet are exposed at the Kansas border.

CAVANAL (CAVANIOL) GROUP.

This group is composed of sandstone, limestone, shale, and coal, and is approximately 3,500 feet thick in the southwestern part of the field. It decreases in thickness both northward and westward. The limestone beds are thin and are confined to the extreme northern and southwestern parts of the field. This group was considered by Dr. Drake to contain all the workable coals known in the Indian Territory field, the lowest one being at the base and the highest at the top.

The lower 2,000 feet of strata are chiefly shale, the sandstone being in local lenticular beds. In the southern part of the field these shales contain two and in places four workable coals. In the northern part but two or possibly three are recognized.

The upper 1,500 to 2,000 feet of strata are more varied. There are three to four sandstone members 50 to 200 feet thick between thicker bodies of shale. Above the uppermost prominent sandstone there are 200 feet of shales. In Cavanal Mountain these shales underlie the coal at the top of the group.

Northward from the southeastern part of the field the sandstone members decrease in thickness, becoming shaly, and limestone beds are introduced in the northwestern part of the Cherokee Nation. The same rocks thin westward, and limestone strata, interstratified with the shales, occur in the eastern part of the Chickasaw Nation, but the decrease in thickness of the group as a whole is not so great as in the northward direction.

The upper coal beds of this group are not known to occur in the southwestern part of the field.

POTEAU GROUP.

The Poteau group is only partially represented in the southeastern part of the Indian Territory coal field, 1,500 to 2,000 feet being exposed in Cavanal and Sansbois mountains, and a less thickness in Sugarloaf and Poteau mountains. In western Choctaw and Creek nations the complete section of the Poteau group is represented by at least 4,000 feet of shale and sandstone interstratified with occasional thin strata of limestone and rarely thin coal. As a whole the shales are thicker than the sandstones. The sandstone beds range from a few feet to more than 400 feet in thickness.

From the region of the Canadian River in northwestern Choctaw Nation the Poteau group becomes thinner both northward and southwestward. The decrease in thickness is especially notable northward. In western-central Cherokee Nation the group is estimated to be less than 1,000 feet in thickness. As in the Cavanal group, the sandstone becomes thin and limestone beds appear interstratified with the shale.

Coal beds have been found in this group, but none are known to be thick enough for profitable working.

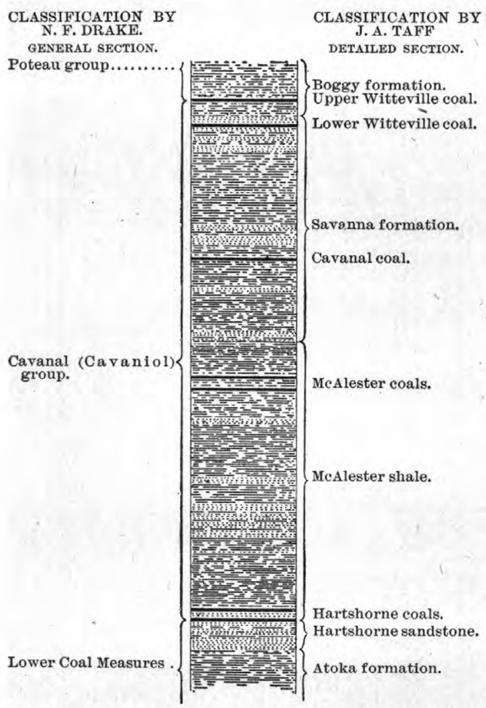


FIG. 34.—Columnar section of coal-bearing rocks in the Indian Territory coal field.

DETAILED SECTION OF COAL-BEARING ROCKS.

A correlation of the general section and detailed section is shown in fig. 34.

The surveyed portion of the coal field in the Choctaw Nation is shown in the geologic map (Pl. XXVI).

HARTSHORNE SANDSTONE.

This sandstone has a maximum thickness of 200 feet and is rarely found to be less than 100 feet. It has associated with it in the upper part and at the top the lower two and most profitable coal beds in this field. Its outcrop is practically continuous across the Choctaw Nation, a distance of 150 miles, and it usually makes a ridge which is a valuable landmark for the location of its associated coals.

M'ALESTER SHALE.

This formation is estimated to be 2,500 feet thick in the eastern portion and about 2,000 feet in the western part of the Choctaw Nation. In the central part there are two and sometimes more local beds of sandstone, which in places attain a thickness of 100 feet.

This formation contains two workable coal beds, besides several thin seams which may become locally thick enough for exploitation. Its outcrop as far as surveyed is accurately shown on the map (Pl. XXVI).

SAVANNA FORMATION.

In the eastern part of the field this formation contains three sandstone members, having thicknesses of 100 to 200 feet, each separated by thicker beds of shale. The thickness of the entire formation is about 1,500 feet. Westward the sandstone members are in places more numerous, but thinner. In the region of McAlester the formation is nearly 1,200 feet thick.

In the eastern part of the field it contains two coal beds of workable thickness. One is just below the middle sandstone member and the other is at the top of the formation, above the upper sandstone member. One of these coal beds has been located near McAlester and worked to a small extent. Coal has not been developed in the formation in the western part of the field, although it is reported to have been found in workable thickness.

BOGGY FORMATION.

This formation is composed of a great number of sandstone and shaly beds, aggregating nearly 3,000 feet in thickness.

The uppermost workable coal bed occurs in this formation in the eastern part of the field, about 250 feet above its base, and is being mined on the east and north sides of Cavanal Mountain. Coal is not known to occur in this formation in the western part of the field.

STRUCTURE.

The structure in the Indian Territory coal field is characterized by both folds and faults, and is illustrated on Pl. XXVI. The anticlines are generally narrower and deeper than the synclines, and there is a tendency to overturn toward the north. The rocks in the north sides of the anticlines often have steeper dips than those in the south sides. Near the great fault on the south side the folds are deepest. Northward, toward the interior, they decrease, becoming shallow undulations. Still farther toward the northwest the folds disappear and the rocks maintain regular low northwestward and westward dips. The folds decrease in number and the folded belt becomes narrower westward, until these structures end near the western border of the Choctaw Nation.

The sections on Pl. XXVI illustrate these folds and show their effect upon the occurrence of the coal.

In the northern part of the field the rocks have a gentle uniform dip to the westward, in the central part, in the region of the Canadian River northwestward, and in the western part toward the north and northeastward. For the most part the dips are less than 100 feet per mile.

In the region of the Ouachita Mountains, immediately southeast of the Indian Territory coal field, the rocks have been greatly folded and there are extensive overthrust faults. The most important fracture is called the Choctaw fault, which extends from Atoka to the Arkansas line along the north side of the Ouachita Mountains. A similar fault of less displacement occurs in Backbone Ridge about 12 miles south of Fort Smith. In this case a simple anticlinal fold is broken and the south limb is thrust northward upon the north limb. Local faulting occurs in the McAlester anticline in the vicinity of McAlester, and also at the border of the coal field north of Atoka.

NUMBER AND EXTENT OF WORKABLE COAL BEDS.

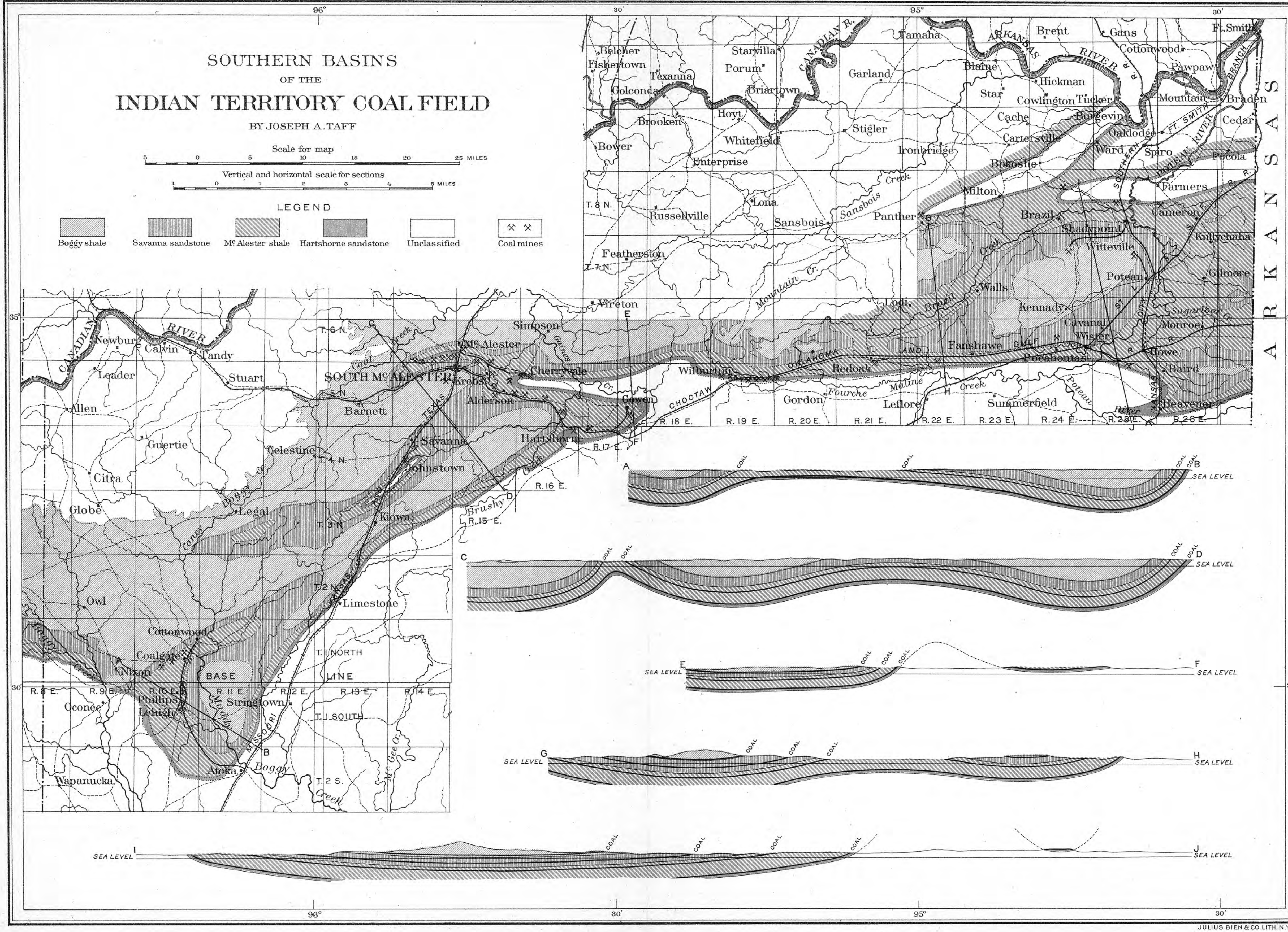
There are seven beds of coal in the Indian Territory coal field which are thick enough to be worked on a commercial scale, besides others which may be locally of workable thickness.

The outcrop of the coal horizons in the southern part of the field, so far as they have been traced, and the axial positions of the folds in which the coals occur, are shown on the map (Pl. XXVI). The term "coal horizon," as used in this report, is intended to mean the position of a coal or association of beds in which coals are known to occur. In some cases coal beds are known to be local in their extent, and throughout a large part of the field their presence has not been determined either by prospecting or by mine working.

The table or summary of mine operations (page 387) contains a condensed history of the mining operations upon each coal bed.

HARTSHORNE COALS.

In the southern part of the field, from the vicinity of Wilburton eastward, there are two coal beds of workable thickness associated with the Hartshorne sandstone. One is near the top of the formation and the other is about 50 feet higher, in the McAlester shale, immediately above the sandstone. The lower bed is 4 to 5 feet and the upper one about 4½ feet in thickness as far as working has been carried, and both are clear of shaly impurities. South of the west end of Poteau Mountain but one of these beds is of workable thickness. From the vicinity of Wilburton westward only the lower bed is known to be thick enough to work. It



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averages about 4 feet in thickness and is generally clean coal throughout. Within the range of the mine workings of the old Gowen mine, 3 miles north of Hartshorne, all the clean coal changes to bony, worthless material. In the north side of the McAlester anticline the coal is nearly upon edge and can not be extensively mined. Also, from the vicinity of Hartshorne to Atoka the same coal is steeply tilted and in places faulted.

In the Lehigh district the lowest bed, known locally as the Atoka coal, occupies the same relative position in the section as the Hartshorne coal. It it not known positively, however, that it is the same bed. It is nearly 4 feet in thickness, is clear of shaly impurities, but is not of as high grade as the Hartshorne coal in the eastern part of the field. In the east side of the Lehigh basin the rocks are steeply upturned and the presence of the coal is not known. This coal horizon is displaced locally by a fault on Clear Boggy Creek, west of Coalgate. It is not known to occur west of the Choctaw-Chickasaw line. From the south end of the Lehigh basin westward the coal is well disposed for working. For the most part the dips are less than 10° and the country is generally level.

Coal in the horizon of the Hartshorne bed occurs in the backbone uplift in the east side of the field, where it is known as the Panama coal. From Hackett, Ark., 15 miles south of Fort Smith, the outcrop of the coal strikes west, dipping south at low angles. This outcrop was traced from the State line westward by way of Doubleday, Adkins, and Panama mines to a point north of Cavanal Mountain. As shown on the map, it continues farther west in the south side of the backbone anticline and then curves northward and eastward on the north side of the fold into Arkansas. The exact location of the coal has not been determined between Pocola and the Kansas City Southern Railway in the north side of the backbone anticline west of Poteau River.

The Panama coal varies in thickness from 3 feet 10 inches to 6 feet. At the Doubleday mine there is 4 feet 11 inches of coal, which is divided near the middle by 7 inches of shale. At the Adkins and Panama mines, farther west, the coal is 4 feet and 3 feet 10 inches respectively. It is clear of shale, and is of excellent quality. In the north side of the Backbone anticline, 1 mile west of Pocola, the coal is 3 feet 7 inches thick, with a thin parting of bony coal near the middle. In the vicinity of Milton the coal is locally divided by shale, and but one stratum of the divided coal is worked in some of the mines. One-half mile east of Milton the coal is 3 feet 8 inches thick, while one-half mile south it is 5 feet 10 inches and is divided by 1 to 1½ feet of shale. About 1 mile southwest of Milton the coal is 6 feet thick with a 5-inch parting of shale 22 inches below the top. One-half mile farther west the shale parting is 3 inches thick.

The Hartshorne coal has not been located or traced north of the Arkansas or Canadian rivers.

The roof of the Hartshorne coal horizon is generally a hard blue or black clay shale. Locally the shale above the lower bed thins, allowing the succeeding sandstone to rest upon the coal. The floor is a very compact blue clay shale, which is commonly known as fire clay.

According to reported observations this coal is much thinner in the northern part of the field than in the southern part, varying from 6 to 18 inches in thickness.

M'ALESTER COALS.

The horizon of the McAlester coals is in the McAlester shale, 600 to 700 feet below the top. There are three districts in the southern part of this field where these coals have been sufficiently developed to be well known. The first occurs between the vicinity of Wilburton and the Arkansas State line; the second between Hartshorne and the vicinity of McAlester; and the third in the vicinity of Savanna.

East of Wilburton two beds are found in this horizon, each about 2½ feet thick, separated by 20 to 60 feet of shale. They are well situated in outcrop near the line of the Choctaw, Oklahoma and Gulf Railroad, but have been mined only to a limited extent owing to the proximity of the thicker Hartshorne coals. One of the beds has been exploited at Panola switch, 4 miles east of Wilburton. Mining operations have been recently begun in both coals at Redoak and at Hughes on the Choctaw, Oklahoma and Gulf Railroad. The McAlester coal is known by prospect in Poteau River Valley southeast of Poteau Station, 2 miles west of Cameron, at the south base of Poteau Mountain about 4 miles west of the State line, and in the valley of Brazil Creek north of Redoak.

These coals in the southeastern part of the field dip at various angles from 5° to 15°, and large areas may be conveniently mined. In the valley of Poteau River, south and west of Cameron, the rocks have even lower dips, but the thickness and quality of the coals are not well known. In the low uplift in the valley of Brazil Creek the coals also have low dips, but have not been sufficiently prospected to determine their workable extent.

Between Wilburton and McAlester the McAlester coals outcrop in the valleys, away from lines of transportation, and in steeply inclined positions, so that they have not been developed, and little is known concerning their extent or quality, except in the local basin at Carbon (Cherryvale), where three mines are now being actively operated.

The McAlester district includes the mines about McAlester, Krebs, Alderson, Carbon, and Dow, in which the coal is mined extensively. The development of these mines is summarized in the table of mining operations on page 387. Until recently, but one coal bed, popularly known as the McAlester coal, has been worked in this district.

At McAlester and Krebs the coal is about 4 feet thick and contains no shaly impurities. At Carbon and Alderson it is 3½ feet, and at Dow it is 3 feet, in thickness.

It has a hard shale roof and floor and but little water or gas is encountered in the mines. The coal is clean, runs generally low in sulphur, and is successfully coked. It mines in block, is sufficiently hard for successful shipping, and is classed as a high-grade bituminous coal.

The structure of the rocks in this district is such that the coal can be mined from both slope and shaft. It is estimated that an area of about 35 square miles of the coal in this district lies at depths of less than 1,000 feet beneath the surface.

From the vicinity of Dow, in the southeast side of the district, the McAlester coal outcrop bears southwestward and may be traced for nearly 30 miles. The dip is steep, however, toward the northwest, the angle being usually greater than 40°. This coal, as well as the Hartshorne coal, which lies below it along this course, is probably disturbed and broken more than is apparent at the surface, owing to its proximity to the overthrust strata along the Choctaw fault at the south side of the field.

In the Savanna district the coal outcrops around an elliptical dome-like uplift in the Savanna anticline, the outcrop upon each side being about 10 miles in length. Except where the coal outcrops across the axial part of the fold at the northeast and southwest ends the dips are steep, usually greater than 45°. As a result, only a small area of coal can be successfully mined, the total being probably less than 10 square miles.

The coal here is about 4 feet thick, and is of practically the same grade as that at McAlester.

A bed known as the Lehigh coal, which is extensively mined at Lehigh and Coalgate, in the southwestern part of the field, is believed to occupy a position a little higher in the section than the McAlester coal. The outcrop of the strata is continuous between this locality and the McAlester district, but on account of the disturbed condition of the rocks the coals can not be successfully traced. In the east side of the Lehigh syncline or basin the rocks are tilted toward the west almost to a vertical position. From the south end of the basin northward past Lehigh and Coalgate, the coal dips generally as low as 4°, and the surface of the country is nearly level. Northeast of Coalgate the rocks rise in an elliptical dome-like structure in the Coalgate anticline, bringing up the coal in both sides of the fold for a distance of about 6 miles. The coal has been prospected here, but not developed. From Coalgate the Lehigh coal strikes westward and the dip increases.

In the western part of the field the coal has not been exploited, and little is known concerning either its thickness or its quality. The area of the Lehigh coal which may be conveniently mined is estimated at approximately 35 square miles.

Although the Lehigh coal generally contains a higher percentage of sulphur than either the McAlester or the Hartshorne coal, its extensive use in locomotives and for general purposes attests its value as a steaming coal.

Dr. Drake located the McAlester coal at many places from the north side of Cavanal Mountain to the Missouri, Kansas and Texas Railroad at Summit, in the Creek Nation. The coal is mined at several places for local use, where the bed was found to be 10 inches to 2 feet in thickness and of good quality.

The coal bed outcropping 4 to 5 miles west of Chelsea, Cherokee Nation, was correlated with the McAlester coal, and was found to run uniformly about 18 inches in thickness. About 100 feet above this, and 4 miles farther west, another coal occurs, 15 inches in thickness.

CAVANAL COAL.

This coal, in the southern part of the field, is found near the middle of the Savanna formation, and is known only in the Cavanal syncline around the base of Cavanal Mountain. Its horizon occurs 100 feet beneath the middle sandstone member of this formation. It has been exploited in the hill above Poteau Station, three-quarters of a mile north of Cavanal Station, and 3 miles west of Wister, where it is 3 to 3½ feet thick.

The coal at the outcrop around the mountain dips at angles varying from 6° to 20°, and it occurs beneath an area of nearly 65 square miles at depths of less than 1,000 feet.

The horizon of the Cavanal coal outcrops in the slopes of Sansbois, Sugarloaf, and Poteau mountains, but the presence of the coal bed itself is not positively known.

A coal bed of workable thickness in the approximate position of the Cavanal coal outcrops in a branch of Fourche Maline Creek, about 4 miles north of Wilburton.

Coal is reported to have been located in the vicinity of Nixon, nearly 8 miles west of Coalgate. Its geologic position is near that of the Cavanal coal, but there is no assurance that it is the same bed.

WITTEVILLE COALS.

There are two beds of coal of workable thickness in the east end of Cavanal Mountain—one at the top of the Savanna formation and the other about 250 feet higher in the section; both are in the Boggy formation. The upper of these is the one placed by Dr. Drake at the top of the Poteau group and named the Mayberry coal. The lower one is known only at this locality. It is 4 feet 8 inches thick and is separated by two variable bands of carbonaceous shale and bony coal. The extent of this coal has not been determined, nor has its quality been tested.

The upper coal bed is about 3 feet 10 inches thick and is separated into two equal benches by a thin parting of shale or bony coal, where it is being mined at Witteville, at the east end of the mountain. The dip of the coal at the outcrop around the mountains varies from 6° to 10°. This dip grows rapidly less, however, toward the center of the mountain, where the rocks are nearly horizontal. The area of each of these coal beds in Cavanal Mountain is about 60 square miles.

The upper Witteville coal is of practically the same quality as the Cavanal and Lehigh coals. It is not so highly bituminous as the Hartshorne or McAlester coals, and has more sulphur. It is most serviceable as a steam-producing coal.

COMPOSITION OF COALS.

The constituents of a coal, as determined by proximate chemical analysis, are water, fixed carbon, volatile combustible matter, ash, sulphur, and phosphorus.

Besides determining the value of a coal as a fuel, the fixed carbon and volatile combustible matter are the essential constituents which determine its value in the production of coke and illuminating gas. Coke is a product of the fixed carbon, and illuminating gas is a product of the volatile matter. In the manufacture of coke the impurities, notably the sulphur and phosphorus, are of vital importance. These elements are highly detrimental where the coke is used in iron smelting. In coking a large part of the sulphur is driven from the coal, especially where it occurs in combination with iron as a sulphide (FeS_2). If it is associated with lime as a sulphate ($CaSO_4$), it will remain in the coke. Ash is simply a negative element, occupying the place of fuel.

The following table shows the composition of coals from the Indian Territory coal field, so far as may be determined by proximate analyses. The fixed carbon and volatile combustible matter are expressed in the right of the table as percentages of the total fuel constituents, and the fuel ratios are given as the index of the fuel qualities of the coal:

Table of proximate analyses of coals from the Indian Territory coal field.

Name of coal bed.	Location of mine.	Moisture.	Volatile combustible matter.	Fixed carbon.	Ash.	Sulphur.	Phosphorus.	Character of coke.	Fuel constituents. Volatile hydrocarbon.	Fuel constituents. Fixed carbon.	Fuel constituents. Fuel ratio.
		Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*		*Per ct.*	*Per ct.*	
Panama (Hartshorne) (?)	Ozark mine, Panama, sec. 21, T. 8 N., R. 25 E.	0.24	15.13	80.	4.63	1.22	0.140	....	15.90	84.10	5.22
Do..................	Doubleday mine, "Top Vein," sec. 7, T. 8 N., R. 27 E.	.17	16.53	78.27	5.03	.88	.033	....	17.44	82.56	4.73
Do..................	Doubleday mine "Lower Vein".....	.17	15.51	71.01	13.31	1.20	.090	Lustrous, hard, and slightly swollen.	17.93	82.07	4.57
Hartshorne............	2 miles southeast of Heavener, sec. 28, T. 5 N., R. 26 E.	.48	22.03	71.28	6.21	1.13	.012	.....do..........................	23.61	76.39	3.23
Do..................	Potter mine, 1½ miles southwest of Howe, sec. 3, T. 5 N., R. 25 E.	.45	20.89	68.86	9.80	.69	.063	Lustrous, firm, and swollen to several times original volume.	23.28	76.72	3.29
Do.[a]	Potter mine No. 1, 1½ miles southwest of Howe, sec. 3, T. 5 N., R. 25 E.	.41	18.23	76.53	3.77	1.06	....	....	19.24	80.76	4.19
Lower Hartshorne.....	West side of Wilburton, Ind. T	1.49	37.83	53.06	7.62	1.01	.023	Lustrous, hard, and slightly swollen.	41.62	58.38	1.40
Upper Hartshorne.....	.....do..............................	1.43	38.15	50.76	9.66	1.38	.052	.....do..........................	42.91	57.09	1.33
Hartshorne............	Shaft No. 1, Hartshorne...............	1.68	41.	51.91	5.41	2.72	.012	Lustrous, with dull-black patches; not swollen.	44.13	55.87	1.26
Do..................	Hughes's mine, 2 miles east of Krebs..	1.04	37.96	55.84	5.16	2.00	.012	Dull; slightly swollen	40.47	59.53	1.47
Do.[b]	Shaft No. 1, Hartshorne...............	2.47	37.79	55.27	3.50	.95	....	....	40.72	59.28	1.45
McAlester	Shaft No. 10, Krebs..................	1.74	37	56.86	4.40	.65	.014	Lustrous, with black patches, moderately swollen.	39.42	60.58	1.54
Do.[c]	Carbon (Cherryvale).................	2.54	30.90	62.37	3.56	.60	....	Fused and slightly swollen.......	33.13	66.87	2.01
Do.[c]	Alderson	2.35	32.42	58.47	4.32	2.42	....	Increased in size one and a half times.	35.67	64.33	1.80
Do..................	Sample s slope, 1 mile west of McAlester.	2.08	37.52	56.02	4.38	.80	.016	Lustrous; not strongly coherent..	40.11	59.89	1.49
Lehigh	Shaft No. 5, Lehigh..................	3.56	41.61	41.12	13.71	4.56	.024	Coherent; lustrous...............	50.30	49.70	.99
Cavanal	¾ miles north of Cavanal Station.....	.22	23.54	66.16	10.08	4.33	.031	Lustrous, firm, and swollen to several times original volume.	26.24	73.76	2.81
Upper Witteville (Mayberry)	Witteville mine, Witteville Station, sec. 15, T. 7 N., R. 25 E.	.48	23.82	66.69	9.01	4.64	.02	.....do..........................	26.32	73.68	2.78

Table of proximate analyses of coals from the Indian Territory coal field—Continued.

Name of coal bed.	Location of mine.	Moisture.	Volatile combustible matter.	Fixed carbon.	Ash.	Sulphur.	Phosphorus.	Character of coke.	Fuel constituents.		
									Volatile hydrocarbon.	Fixed carbon.	Fuel ratio.
		Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*		*Per ct.*	*Per ct.*	
Upper Witteville (Mayberry).	Mayberry mine, sec. 11, T. 7 N., R. 24 E.	.55	23.02	64.21	12.22	5.81	.20	Lustrous, firm, and swollen to several times original volume.	26.39	73.61	2.78
McAlester (?)[c]	2 miles west of Stigler, Choctaw Nation.	1.66	23.01	72.47	1.92	.91	....	Increased in size about ten times	24.10	75.90	3.15
Do[c]	3 miles northwest of Sansbois	1.60	24.83	68.69	2.95	1.90	....	do	26.55	73.45	2.76
Do[c]	1½ miles northwest of Starvilla, Cherokee Nation.	1.25	22.49	62.18	7.88	6.18	....	....	26.56	73.44	2.77
Do[c]	4½ miles west of Chelsea, Cherokee Nation.	6.26	27.16	64.17	1.84	.56	....	Increased in size about one and a half times.	29.73	70.27	2.36
Mayberry (?)[c]	12 miles south of Okmulgee, Creek Nation.	6.30	30.78	59.92	2.11	.87	....	do	33.93	66.07	1.94
Do[c]	4 miles east-northeast of Reams, Choctaw Nation.	1.62	32.97	55.79	9.65	....	....	do	37.14	62.86	1.69

[a] Furnished by the Mexican Gulf Coal and Transportation Company. [b] Analysis by A. S. McCreath, State chemist of Pennsylvania. [c] Analysis by N. F. Drake.

The Mexican Gulf and Transportation Company produces coke from the Hartshorne coal at the Potter mines near Howe. A battery of 100 ovens at the place manufactures coke from the unwashed[a] slack. The coke is marketed in Mexico and gives good results. The analysis of the coal from this mine by the United States Geological Survey is given in the table on page 384.

The analysis of the coal and coke furnished by the mining company is as follows:

Analysis of coke made from Hartshorne coal.

	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.
Coal	0.41	18.23	76.53	3.77	1.05
Coke	.48	.96	90.43	7.45	.68

This analysis indicates a higher grade of coal than that collected by the Survey from market cars filled at the same mine. In either case the coal is low in sulphur and high in fixed carbon and should produce a high-grade coke.

The same company operates 30 coke ovens at Alderson, producing coke from the McAlester coal. The same coal is coked in 80 ovens at Krebs by the Osage Coal and Mining Company. An analysis of this coal by the St. Louis Sampling and Testing Works is as follows:

Analysis of McAlester coal.

Moisture	2.18
Volatile matter	29.79
Fixed carbon	62.82
Ash	4.54
Sulphur	.67

The phosphorus in this coal as determined by the Survey is 0.014 per cent. The company reports that the coal produces 50 per cent of coke, which is finely porous and strong.

DEVELOPMENT OF COAL MINING.

Coal mining in Indian Territory on a commercial scale began in the vicinity of McAlester with the location of the Missouri, Kansas and Texas Railroad in 1872. In the following year the Osage Coal and Mining Company began operations, connecting its mines by a branch road with the main line at McAlester, and up to the present time the exploitation of coal has gradually increased, extending nearly across the south side of the field. The industry is represented by 28 companies and several individuals, and during the year 1900 over 1,900,000 tons of coal were produced. Active mining operations began at Savanna and at Lehigh in 1881. Since 1887 small mines only have

[a] L. W. Bryan, annual report of the mine inspector for Indian Territory for the year ending June 30, 1900.

operated at Savanna, while in the Lehigh district active exploitation is still carried on.

The McAlester, Savanna, and Lehigh districts are dependent for transportation facilities on the Missouri, Kansas and Texas Railroad.

The Frisco Railroad was built across the eastern part of Indian Territory about 1885 and furnishes transportation for this part of the coal field, but the interests of the company were in the coals of the western part of the Arkansas field, and the Indian Territory coals along its line have received but little attention until recently.

The Choctaw, Oklahoma and Gulf Railroad, which runs through the south side of the field nearly upon the strike of the coals from South McAlester eastward, furnishes transportation for the markets in the region between western Oklahoma and the Mississippi River.

Still later the Kansas City Southern Railroad was built across the east side of Indian Territory, approaching or crossing all the coal beds known in this part of the field. This road gives transportation north to Kansas and Missouri and south to the Gulf of Mexico at Port Arthur.

The development of the coal in the eastern part of the field has been more recent than that in the western part, owing to the difference in transportation facilities.

The lower coals increase in quality from west to east in the southern part of the field, and a number of beds not known to be productive in the western part are now worked in the eastern part. It is considered, therefore, that the eastern districts will soon surpass the western in the production of coal.

The coal beds in the northern part of the field are thinner and probably less numerous than in the southern, but the quality of the coals, so far as analyses have been made, shows them to be practically the same.

Summary of mining operations.

Station.	Company.	Mine.	Location.	Name of coal bed worked.	Thickness of coal.
					Ft. in. Ft. in.
Gowen	Kali-Inla Coal Co ..	No. 3 shaft...	Sec. 26, T. 5 N., R. 17 E.	Hartshorne........	3 6 to 5 0
Wilburton...	McAlester Coal and Mineral Co.	Upper slope..	Sec. 8, T. 5 N., R. 19 E.	Upper Hartshorne.	4 6
		Lower slope .	.....do.........	Lower Hartshorne.	5 0
Do.......	Wilburton Coal and Mining Co.	Slope No. 1 ..	Sec. 10, T. 5 N., R. 19 E.	Upper Hartshorne.	4 6
		Slope No. 2...	....	Lower Hartshorne.	5 0
		Slope No. 3...	....	.....do............	3 6
		Slope No. 4...	....	....	....
Do.......	Eastern Coal and Mining Co.	Shaft........	Sec. 7, T. 5 N., R. 19 E.	Hartshorne........	4 0
Ola..........	Ola Coal and Mining Co.	Slope No. 1...	Sec. 11, T. 5 N., R. 19 E.	Lower Hartshorne.	5 0
	.....do.............	Slope No. 2...	.....do	.....do............	5 0
	.....do.............	Slope No. 3...	.....do.........	Upper Hartshorne.	4 6
	.....do.............	Slope No. 4...	Sec. 7, T. 5 N., R. 20 E.	Lower Hartshorne.	5 0 to 5 4

Summary of mining operations—Continued.

Station.	Company.	Mine.	Location.	Name of coal bed worked.	Thickness of coal.
					Ft. in. *Ft. in.*
Panola	....	Slope	Sec. 5, T. 5 N., R. 20 E.	McAlester	4 2
Redoak	R. H. Kilpatrick	do	Sec. 3, T. 5 N., R. 21 E.	do	....
Do	Turkey Creek Coal Co.	Slope No. 1	Sec. 34, T. 6 N., R. 22 E.	do	2 10
Wister	Caston Coal Co	Slope	Sec. 28, T. 6 N., R. 24 E.	Cavanal (?)	3 0
Howe	Mexican Gulf Coal and Transportation Co.	Shaft No. 1	Sec. 3, T. 5 N., R. 25 E.	Hartshorne	....
		Shaft No. 2	....	do	....
Heavener	Milby & Dow	Slope	Sec. 28, T. 5 N., R. 26 E.	Lower Hartshorne (?).	3 0
Cavanal	Crescent Coal and Mining Co.	do	Sec. 17, T. 6 N., R. 25 E.	Cavanal	3 3
Witteville	Indianola Coal and Railway Co.	do	Sec. 15, T. 7 N., R. 25 E.	Upper Witteville	4 0
Sutter	Choctaw Coal and Mining Co.	do	Sec. 11, T. 7 N., R. 24 E.	do	....
Jenson	Jenson Coal Co	....	Sec. 9, T. 8 N., R. 27 E.	Panama	2 10
Do	Kansas and Texas Coal Co.	Doubleday slope.	Sec. 7, T. 8 N., R. 27 E.	do	5 6 to 7 0
Cameron	C. G. Adkins	Slope	Sec. 21, T. 8 N., R. 26 E.	do	4 0
Panama	Ozark Coal and Railway Co.	do	Sec. 21, T. 8 N., R. 25 E.	do	3 10
Hartshorne	Kali-Inla Coal Co	Shaft No. 1	Hartshorne	Hartshorne	4 6
Haileyville	Haileyville Coal and Mining Co.	Shaft and slope.	Haileyville	do	4 6
Krebs	Osage Coal and Mining Co.	Shaft No. 5 Shaft No. 8 Shaft No. 11 Shaft No. 11½ 3 slopes	Krebs	McAlester	3 10
Carbon (Cherryvale).	Kansas and Texas Coal Co.	Slope No. 50 Slope No. 52 Slope No. 67	Carbon	do	3 6
Alderson	Kali-Inla Coal Co	Slope No. 7 Slope No. 5 Slope No. 15	Alderson	do	3 6
Do	McAlester Coal Co	Slope	do	do	3 6
Dow	Milby & Dow Coal and Mining Co.	Shaft and slope.	Dow	do	3 6
McAlester	D. Edwards and Son.	3 slopes	McAlester	do	4 0
Do	McEvers & McAlester.	Slopes	1 mile west of McAlester.	do	5 ±
Buck	McAlester Coal and Mining Co.	Slope No. 2 Slope No. 3 Slope No. 12	Buck, 4 miles west of McAlester.	do	4 0
Savanna	R. Searls	2 slopes	Savanna	do	3 +
Do	M. Perona	Slope	do	do	3 0
Atoka	St. Louis and Galveston Coal and Mining Co.	Slope	10 miles west of Atoka.	Atoka	4 0
Lehigh	Atoka Coal and Mining Co.	Shaft No. 5½. Shaft No. 6 Shaft No. 7	Lehigh	Lehigh	4 6
Coalgate	Southwestern Coal and Improvement Co.	Shaft No. 4	Coalgate	do	5 0
		Shaft No. 9	do	do	

Summary of mining operations—Continued.

Station.	Company.	Mine.	Location.	Name of coal bed worked.	Thickness of coal.	
					Ft. in.	*Ft. in.*
Coalgate	Perry Bros. Coal Co.	Slopes	Coalgate	Lehigh		4 0
Do	J. B. McDougal	do	do	do		4 0
	The Horse Pen Coal and Mining Co.	Strip pits	Collinsville region.			
Dawson	Texas Coal Co	do	Dawson			2 10

ARKANSAS COAL FIELD.

INTRODUCTION.

The summary of the present knowledge of the geology of the Arkansas coal field is based upon the published results of the Arkansas geological survey. In addition to this Dr. J. C. Branner has kindly furnished the accompanying map (Pl. XXVII) of the coal-bearing rocks of Arkansas from his unpublished final report.

LOCATION AND BOUNDARIES.

The Arkansas coal field is situated in the hydrographic basin of the Arkansas River in western-central Arkansas. It is a direct continuation of the Indian Territory coal field and extends from the west line of the State down the river valley nearly 75 miles. Its extreme width near the west end is about 50 miles. With the exception of an arm of coal-bearing rocks in Poteau and Whiteoak mountains at the south side, it contracts abruptly eastward to about 25 miles and so continues to the east end.

The north edge of the field lies upon the southern foothills of the Boston Mountains, which are the southern limit of the Ozark highlands. The southern border of the field approaches the Ouachita Mountain ridges, which extend from the vicinity of Little Rock westward into Indian Territory.

AGE OF THE COAL-BEARING ROCKS.

The coal-bearing rocks in Arkansas have not been classified in regard to age, except in the general sense that they belong to the Pennsylvanian (Upper Carboniferous) series.

The lowest and most productive coal horizon, at the base of the upper coal-bearing strata; in the western part of the field, including the beds mined at Bonanza, Hacket, Jenny Lind, and Huntington, is recognized to be the same as the Panama and Hartshorne in Indian Territory. These beds occur in rocks which correspond in age to the Lower Coal Measures in the Pennsylvania and Missouri sections. The coal in the lower coal-bearing division in the eastern part of the Arkansas field, therefore, belongs to the Lower Coal Measures also.

The horizon of the McAlester coal of Indian Territory, which belongs to the Upper Coal Measures, occurs more than 1,000 feet above the Hartshorne or Bonanza, Hacket, and Huntington coal. Coals have been opened at many places in the western part of the Arkansas field in the formation containing the McAlester coal, but no attempt has been made to correlate them with the latter.

The horizon of the highest coal bed of importance in Indian Territory, which is mined at Witteville, in the east end of Cavanal Mountain, nearly 12 miles west of the State line, should occur near the top of Sugarloaf and Poteau mountains in western Arkansas. This coal horizon is several thousand feet below the top of the Upper Coal Measures in the Indian Territory section.

STRATIGRAPHY.

While the stratigraphy of the Arkansas coal field has been studied in considerable detail, the results have not yet been published. As a consequence but meager information can be given here concerning it. In Mr. Winslow's report[a] the following general statements are made regarding the stratigraphy of the field:

> Sandstones and shales make up almost the entire list of rocks. With the shales is associated the coal, while some thin beds of iron carbonate concretions also break the uniformity. An occasional layer of calcareous shale is also seen, but nothing that deserves the distinction of the term limestone bed is found within the area discussed. * * * The shales are either argillaceous or arenaceous; sometimes light gray in color, sometimes dark gray, or even black and bituminous. * * * The sandstones may be either massive, thinly bedded, flaggy, or even shaly. They are generally highly siliceous and of a light-gray color. * * *
>
> More than ten different groups of sandstone strata have been identified, separated by hundreds of feet of shale, the whole making a most imposing column. [It is not practicable to construct a representative section, for he states] that these different stratigraphic groups are not persistent. In places a ridge-forming sandstone becomes so attenuated as to have no topographic prominence. A sandstone bed heavy and massive in one place may, within a few miles, become flaggy or shaly.

In order to properly discuss the distribution of coal, Mr. Winslow separated the coal-bearing strata into three divisions. This classification includes:

The Upper or Western coal-bearing division.

The Intermediate barren division.

The Lower or Eastern coal-bearing division.

Thin coal, of little economic importance, is also reported to occur below the Lower coal-bearing strata.

LOWER OR EASTERN COAL-BEARING DIVISION.

This division is described as including, in the eastern part of the field, a "body of dark fissile shale," not less than 250 feet thick. The

[a] Arkansas Geological Survey, Ann. Rept., 1888, Vol. III.

ARKANSAS COAL FIELD, FROM UNPUBLISHED MAPS OF THE ARKANSAS GEOLOGICAL SURVEY

Furnished by John C. Branner

Scale

5 0 5 10 15 20 25 MILES

one economically important coal bed occurs near the base of this shale. The shale rests upon a massive sandstone locally termed "bed rock." The coal in this division diminishes in thickness westward, and can not be traced west of the center of the field.

The base of the Lower coal-bearing division, and approximately the outcrop of the lowest productive coal horizon in the eastern parts of the field, so far as known, coincides with the border of the coal-bearing strata as shown on the map. Since the map is intended by Dr. Branner to include only the rocks that contain coal, the border of the mapped area west of the region of Paris is located practically upon the lowest coal at the base of the Upper coal-bearing division. This includes also the arm of coal-bearing rocks at the southern border of the field. In passing from the base of the Lower to the base of the Upper coal-bearing division in the central part of the field, the border of the coal-bearing strata as mapped transgresses diagonally across the Intermediate barren division.

INTERMEDIATE BARREN DIVISION.

This has not been discussed, more than to give it a place in the map between the Upper and Lower coal-bearing divisions. It is known, however, from the general description of the strata of the coal field, to be composed of shale and sandstone.

UPPER OR WESTERN COAL-BEARING DIVISION.

This group of strata consists of a series of sandstone and shale beds, having a thickness of probably 3,000 feet. In it have been recognized three beds of coal. Besides these there are probably others of more local occurrence. Of the three recognized, the lowest is the thickest and at the same time the most extensive in area. It occurs practically at the base of the division, resting nearly upon a persistent and usually massive sandstone. This is the coal which is exploited in all of the most productive mines in the western part of the field, besides those at Panama and Howe, in Indian Territory. The sandstone below it is correlative with the Hartshorne sandstone.

The outcrop of the coal is shown on the map approximately by the line limiting the coal-bearing rocks in the southwestern part of the field.

STRUCTURE.

The Arkansas coal field lies in a wide unsymmetrical trough between the greatly folded region of the Ouachita Mountains on the south and the very slightly folded rocks of the Ozark uplift on the north. The Arkansas River, from Fort Smith to the vicinity of Dardanelle, flows in the axial portion of this trough.

The structure of the field, broadly speaking, is unsymmetrical in that the folding south of the central part of the trough is more extensive than to the north. Like the structure in the southeastern part of the Indian Territory coal field, the folding decreases in intensity northward. In the Indian Territory field, as the folds die out they blend into a slightly variable monoclinal structure, with persistent, though low, inclination toward the northwest; while in the Arkansas field, as the local folding ceases the rocks rise toward the north in the southern monoclinal slope of the Boston Mountains.

The folds are generally parallel and trend approximately east and west. They resemble the Appalachian type of structure, especially in their tendency to overturn in one general direction. Some of the anticlinal folds, especially near the south side of the field, have steeper dips on their north sides. Not far south of the coal field in the Ouachita uplift the folded structure is excessively developed.

The location and trend of the folds are indicated upon the map by the outlines of the coal-bearing strata. The long arm of coal-bearing rocks in the south side of the field lies in the Poteau synclinal fold and forms Poteau and Whiteoak mountains.

The small detached areas in the southern and southeastern parts of the field are also remnants of coal-bearing strata which occurred in synclines.

The Sugarloaf syncline extends eastward from Sugarloaf Mountain, in the north part of T. 4 N., R. 32 E., toward Huntington. It is a shallow canoe-shaped trough rising toward the east in the Huntington mining district.

The anticlinal fold of Backbone Ridge enters the State near Jenson and bears nearly east. Between the State line and the vicinity of Greenwood the rocks in the central part of the anticline are closely folded, and, in part, broken and faulted. Opposite Greenwood the fold is deflected slightly northward and then pitched gradually eastward.

The folding of the strata in the eastern part of the field can be inferred from the outlines of the coal-bearing rocks as represented on the map (Pl. XXVII). A prominent anticlinal fold west of Piney and another east of Allister may be located by the elevation of barren strata occurring beneath the coal horizons. Folds of less prominence occur in the central part of the field, but they have no special economic importance at the present time.

NUMBER AND EXTENT OF WORKABLE COAL BEDS.

There are two coal horizons in the Arkansas field which are of special importance, and the coals in them are being extensively developed. One of these beds (the Huntington coal) occurs at the base of the Western or Upper division, and the other (the Spadra coal) at the base of the Eastern or Lower division.

HUNTINGTON COAL.

The Huntington coal is not known to occur in the eastern part of the field, except possibly near Philpot, and in a few other small areas. Some coal mined in the vicinity of Paris may belong to this horizon. Coals in these localities, however, are thinner and therefore of less value than the Huntington coal in the western part of the field.

It will be observed by reference to the map that the Huntington coal occurs at the base of the coal-bearing rocks, and would seemingly be correlated with the Spadra coal in the eastern part of the field. The coals are not considered the same, however, as has already been stated. From the vicinity of Charleston west the Huntington coal outcrops approximately along the border of the coal-bearing rocks. It varies from 3 to 6 feet in thickness in the mines now in operation. Details of location and thicknesses of coal are given under "Summary of mining operations" (p. 401).

SPADRA COAL.

This horizon occurs at the base of the Lower coal-bearing division. The outcrop of the Spadra coal is located approximately east of the vicinity of Paris, at the border of the coal-bearing strata as outlined on the map. The Spadra coal in the mines reporting operation in the eastern part of the field varies from 3 feet to 3 feet 10 inches in thickness. Details of this coal, also, are given on page 401, under "Summary of mining operations."

OTHER COALS.

In the slopes of Poteau and Sugarloaf mountains, and in the central part of the field east of Fort Smith, numerous locations have been made on other coals which occur stratigraphically above the Huntington bed. The character of these, so far as can be given here, is shown in the table below, with the references to the Huntington and Spadra coals.

CHARACTER OF THE ARKANSAS COALS.

CHEMICAL ANALYSES.

The following table of proximate chemical analyses of the Arkansas coals will give an estimate of their qualities. The table is from Mr. Winslow's report.[a] The numbers of the analyses in the table correspond with the same numbers on the map, and give locations of coal openings where the samples were taken.

Analyses Nos. 1, 2, 4, 6, 7, 9, 10, 12, 13, 17, and 19 are of coal from the horizon of the Huntington bed. It is probable that Nos. 5, 15, and 18 are also from this horizon. Nos. 20, 21, 22, 23, 24, 25, 26, and 27 are of coal from the Spadra horizon. Nos. 3, 8, 11, 14, and 16 are from beds not located stratigraphically.

[a] Ann. Rept. Geol. Survey Arkansas for 1888, Vol. III.

Analyses of Arkansas and other coals,

ARKANSAS BITUMINOUS.

No. of sample.	General information.				Physical properties.		
	Name of pit or mine.	County.	Thickness of coal.	How sampled.	Appearance.	Specific gravity.	Color of ash.
			Ft. in.				
1	Carnall's drift	Sebastian.	3 10	From pile in drift, been dug 2 years.	Shaly and friable.	1.469	Pinkish red ..
2	Page's pit	.....do	2 +	From fresh fragments at mouth of pit.	Shaly, pyrites films, mineral charcoal.	1.300	Reddish gray.
3	Baxley pit	Logan	2 6	From pile at mill in Paris, dug 8 months.	Somewhat shaly, rather compact.	1.295	Light red.....
4	Hackett City shaft, Kansas and Texas Coal Co.	Sebastian.	3 0	From 5 market cars.	Shaly and friable.	1.341	Pinkish gray.
5	Pickartz's drift....	Franklin .	2 0	From pile fresh coal on dump.	Shaly, with iron stain.	1.308	Brick red.....
6	Huntington slope, Kansas and Texas Coal Co.	Sebastian.	6 6	From 2 market cars.	Very friable, somewhat shaly.	1.293	Reddish brown.

ARKANSAS SEMIBITUMINOUS.

No. of sample.	Name of pit or mine.	County.	Thickness of coal.	How sampled.	Appearance.	Specific gravity.	Color of ash.
7	Claiborne's pit	Sebastian.	5 6	From fresh face of coal in pit.	Slightly shaly, very friable.	1.303	Bright red....
8	Lewis's pit	Franklin .	1 2	From pile at pit, dug 1 year.	Shaly and very friable.	1.320	Dark red......
9	McConnel's shaft..	Sebastian.	2 9	From pile fresh coal on dump.	Quite shaly and friable.	1.296	Light red.....
10	Greenwood shaft..	.....do	6 0	.....do	Somewhat shaly, but rather compact.	1.300	Drab ....
11	Sullivant and Boling.	Crawford .	1 2	From small pile at pit, dug 1 year.	Shaly and slightly friable.	1.366	Dark lavender.
12	Bocquin and Reutzel shaft.	Sebastian.	5 0	From pile fresh coal on dump.	Slightly shaly and friable.	1.342	Lavender red.
13	Gwyn's drift	.....do	4 10	.....do	Rather friable and shaly.	1.315	Pink..........
14	Carlan's slope....	Logan	....	From small pile at slope, dug 1 month.	Brittle, a little pyrites.	1.313	Brownish red.
15	Moomaw's pit.....	Franklin .	1 8	From scattered fragments, recently dug.	Shaly, with pyrites.	1.352	Yellowish red.
16	Grave's drift......	Crawford .	1 6	From pile fresh coal at drift.	Hard, but brittle, and somewhat shaly.	1.313	Dark lavender.
17	Petty's slope	Sebastian.	5 0	From pile fresh coal on dump.	Shaly and friable.	1.384	Lavender red.
18	Philpott shaft.....	Johnson ..	1 9	.....do	Rather friable, somewhat shaly.	1.292	Yellowish red.
19	Watt's slope.......	Sebastian.	3 10	From scattered fragments recently dug.	Slightly shaly and friable.	1.392	Dark lavender.
20	Felker slope	Franklin .	1 8	From large pile on dump, dug 6 months.	Rather shaly, somewhat friable.	1.317	Yellowish red.

classified according to their fuel ratios.[a]

ARKANSAS BITUMINOUS.

Chemical composition.					Fuel ratio.	Results of laboratory coking tests—appearance of product.	Per cent of product.
Water.	Volatile hydrocarbons.	Fixed carbon.	Ash.	Sulphur.	C./V. H. C.		
Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*			
5.259	17.655	61.975	13.620	1.491	3.51	Product not at all fused, fragments retained their original shapes.	77.4
.852	16.394	78.222	3.297	1.235	4.77	Product well fused and took the shape of the crucible.	81.2
1.232	15.745	75.335	5.281	2.407	4.79	Product very well fused and took the shape of the crucible.	83.0
.853	14.916	73.869	9.038	1.324	4.95	Product well fused and roughly took the shape of the crucible.	82.3
.702	15.877	78.998	3.561	.862	4.97	Product well fused and took the shape of the crucible.	82.6
.928	15.546	77.538	4.845	1.143	4.99	.....do........	80.6

ARKANSAS SEMIBITUMINOUS.

0.943	15.542	78.355	4.008	1.152	5.04	Product well fused, but roughly took shape of crucible.	81.0
.883	15.230	77.200	4.236	2.451	5.07	Product well fused and took shape of crucible.	81.0
.600	15.381	78.298	4.579	1.142	5.09	Product well fused and took roughly the shape of crucible.	83.6
.818	14.866	75.821	5.973	2.522	5.10	Product very well fused and took the shape of the crucible.	83.6
.761	12.950	67.131	14.200	4.958	5.19	Product well fused and took roughly the shape of the crucible.	82.8
.746	14.980	77.867	5.003	1.404	5.20	Product irregularly fused, fragments well fused.	81.6
.892	14.577	77.092	6.245	1.193	5.29	Product very well fused and took shape of crucible.	82.2
.846	14.670	78.401	4.710	1.373	5.34	Product well fused and took the shape of the crucible.	83.3
.663	14.887	79.812	3.272	1.366	5.36	.....do........	82.2
.566	13.901	75.066	7.614	2.853	5.40	.....do........	82.3
1.779	13.330	76.225	7.046	1.620	5.72	Product well fused and took roughly the shape of the crucible.	83.04
.869	14.133	80.915	3.090	.993	5.73	Product well fused and took shape of crucible.	84.6
.743	12.618	72.608	9.965	4.066	5.75	Product not thoroughly fused and took roughly the shape of the crucible.	83.0
1.128	13.211	81.277	3.220	1.164	6.15	Product partially fused, but fragments partly retained original shapes.	85.0

[a] The analyses of Arkansas coals were made by Dr. R. N. Brackett, chemist of the Arkansas geological survey, and Mr. J. P. Smith, assistant.

Analyses of Arkansas and other coals,

ARKANSAS SEMIBITUMINOUS—Continued.

No. of sample.	General information.				Physical properties.		
	Name of pit or mine.	County.	Thickness of coal.	How sampled.	Appearance.	Specific gravity.	Color of ash.
			Ft. in.				
21	Ouita slope, Ouita Coal Co.	Pope......	2 6	From 1 market car.	Rather shaly, not very friable, little calcite.	1.339	Yellowish brown.
22	Eureka shaft, Stiewel & Co.	Johnson..	3 0	.....do	Compact, not very shaly.	1.345	Brownish drab.
23	Coal Hill shaft, Stiewel & Co.	.....do....	3 10	.....do...........	Slightly shaly, not very friable, calcite films.	1.333	Drab ....
24	Allister slope, Ouita Coal Co.	.....do....	3 7	From 2 market cars.	Slightly friable, calcite films.	1.320	.....do........
25	Mason's drift	.....do....	1 4	From small pile, dug 1 year previous.	Very friable ..	1.339	Yellowish red.
6	Harkreader's well.	.....do....	3 6(?)	From small block, dug 1 year.	Shaly and slightly friable.	1.318	Dark brownish red.

ARKANSAS SEMIANTHRACITE.

27	Shinn slope	Pope......	1 10	From fresh face of coal.	Compact, little shale and pyrites, calcite films.	1.346	Pinkish gray.
	Mean of the 27 samples.	....	....	....	....	1.331	....

OTHER COALS.

Locality and character.	Authority.	Physical properties.	
		Specific gravity.	Color of ash.
Connellsville coal, Pennsylvania, standard coking coal	E. V. d'Invilliers..	....	....
Flat Top, Pocahontas coal, Virginia, "semibituminous" coking coal.	.....do	....	....
Charleroi, France, produces well-formed coke	Percy............	....	....
Westmoreland Gas Coal Company, Pennsylvania, gas and coking coal.	E. V. d'Invilliers..	....	....
Cumberland coal, Maryland, "semibituminous," excellent steaming coal.	.....do	....	....
Broad Top coal, Pennsylvania, "semibituminous," good forge and steaming coal.	.....do	....	....
Bernice coal, Pennsylvania, semianthracite, good steaming and domestic coal.	McCreath.........	....	Gray..........
Wilkesbarre, Pa., anthracite	.....do	1.614	Reddish gray.
Belleville coal, Illinois, average from 6 mines	Worthen	1.300	....
Corona coal, Alabama....................................	Smith	1.320	....
Rich Hill coal, Missouri..................................	Potter	....	....
Kansas coals, average of 38 samples.......................	Bailey	....	....
St. Bernard Coal Company (No. 11), Western coal fields, Kentucky.	Procter	....	....

classified according to their fuel ratios—Continued.

ARKANSAS SEMIBITUMINOUS—Continued.

Chemical composition.					Fuel ratio.	Results of laboratory coking tests—appearance of product.	Per cent of product.
Water.	Volatile hydrocarbons.	Fixed carbon.	Ash.	Sulphur.	C. / V.H.C.		
Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*			
.980	12.200	76.817	8.174	1.829	6.29	Product not at all fused, fragments retain their original shapes.	87.6
1.100	11.278	72.835	12.042	2.745	6.46	Product not at all fused, fragments retain original shapes.	89.2
1.017	10.841	76.119	8.351	3.672	7.02	Product partially fused, fragments retain somewhat original shapes.	87.2
1.178	10.475	76.494	8.322	3.531	7.30	Product partially fused, fragments little changed.	86.5
1.116	11.006	80.860	5.863	1.155	7.34	Products slightly fused, and fragments retain roughly original shapes.	86.7
1.563	10.347	78.910	6.313	2.867	7.62	Product not at all fused, fragments retain original shapes.	86.6

ARKANSAS SEMIANTHRACITE.

1.058	8.410	75.434	11.750	3.346	8.96	Product not at all fused, fragments retain original shapes.	88.4
1.114	3.739	76.276	6.763	2.009	5.792	....	83.654

OTHER COALS.

Chemical composition.					Fuel ratio.	Results of laboratory coking tests—appearance of product.	Per cent of product.
Water.	Volatile hydrocarbons.	Fixed carbon.	Ash.	Sulphur.	C. / V. H. C.		
Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*			
1.260	30.107	59.616	8.233	.784	1.98	Product well fused, and took shape of crucible.	78.6
1.011	18.812	74.256	5.191	.730	3.95	Product fused, and took shape of crucible..	84.43
....	15.570	80.880	3.550	....	5.20	....	......
1.427	37.521	54.921	5.418	.713	1.46	....	......
.958	19.139	72.708	6.408	.787	3.79	....	......
.594	17.551	71.334	9.545	.976	4.07	....	......
1.295	8.100	83.344	6.230	1.031	10.30	....	......
2.493	4.342	83.967	8.544	.653	19.33	....	......
6.420	37.140	48.990	7.560	....	1.32	....	......
1.550	37.740	58.810	1.900	1.950	1.56	....	......
5.050	34.400	44.500	16.050	....	1.29	....	......
4.792	39.617	45.396	10.193	....	....	....	......
4.720	36.000	53.510	6.130	2.980	1.49	....	......

The following are analyses of the commercial coals furnished by the mining companies:

No.	Location.	Name of coal.	Water.	Volume combustible matter.	Fixed carbon.	Ash.	Sulphur.
1	Jenny Lind....	Huntington....	0.94	13.64	76.73	7.12	....
2	Huntington....	.....do	1.33	14.03	77.83	5.63	1.33
3	Denning........	Spadra	1.07	11.21	78.01	8.13	....

Nos. 1 and 3. Western Coal and Mining Company, Jenny Lind, Ark. St. Louis Sampling and Testing Works, analyst, 1897.

No. 2. Prairie Creek Coal Company, Huntington, Ark. Analysis by Bureau of Equipment, Navy Department, Washington, D. C., 1899.

COKING TESTS.

Mr. Winslow states[a] "the results of the coking tests attached to the table of analysis do not of course establish the capabilities of the different coals for the production of coke on a commercial scale. But the negative results are final. That is, a coal which will not coke in a crucible will not do so in the oven. The positive results, however, establish only a scale of probabilities. These results may therefore be interpreted as follows:

"Will probably coke: Nos. 2, 3, 5, 6, 8, 10, 13, 14, 15, 16, 18.

"Will possibly coke: Nos. 4, 7, 9, 11, 12, 17, 19.

"Will probably not coke: Nos. 20, 23, 24, 25.

"Will certainly not coke: Nos. 21, 22, 26, 27."

STEAMING TESTS.

Since a large part of the Arkansas coals are demanded for the production of steam, tests of the two principal coals from the Arkansas field made by the St. Louis Sampling and Testing Works, William B. Potter, manager (June, 1897), are submitted. The efficiency of these coals is compared with that of the standard steaming coal in the United States:

[a] Op. cit., p. 59.

Evaporative tests of Arkansas coals from mines of Western Coal and Mining Company compared with Pocahontas (West Virginia) lump coal.

	Pocahontas (W. Va.) lump.	Denning, Ark. (Spadra coal).	Jenny Lind, Ark. (Huntington coal).	Coal Hill (Spadra coal).[a]	Huntington, Huntington coal.[a]
Duration of test .... hours..	8.00	9.00	9.00	7.50	6.60
Mean temperature of boiler room, degrees F	77.00	77.00	79.00	58.00	56.00
Mean temperature of outside air, degrees F	72.00	75.00	80.00	59.00	43.00
Condition of weather	Clear.	Fair.	Clear.	Rainy.	Rainy.
Mean steam pressure above atmosphere, by gage .... pounds..	75.30	77.00	75.70	70.00	68.70
Mean temperature of steam .. degrees F..	320.00	321.00	320.00	315.90	315.50
Mean absolute steam pressure .. pounds..	90.00	91.70	90.40	84.80	83.40
Mean height of water level ...... inches..	6.50	6.50	6.50	6.56	6.50
Mean percentage of water entrained in steam	Dry.	Dry.	Dry.	3.00	2.00
Mean temperature of feed water, degrees F	80.40	80.90	80.80	64.80	171.00
Water apparently evaporated ... pounds..	18,576.00	20,834.00	20,021.00	9,342.00	11,762.00
Equivalent evaporation to dry steam from and at 212° F .... pounds..	21,767.00	24,503.00	23,453.00	10,821.00	12,429.00
Equivalent evaporation per hour .. do....	2,721.00	2,722.50	2,606.00	1,442.80	1,883.00
Equivalent evaporation, boiler horsepower	78.80	78.89	75.50	41.80	54.60
Equivalent evaporation per hour per square foot of heating surface. pounds..	.373	.373	.357	1.98	2.58
Weight of coal used, plus coal equivalent of wood .... pounds..	2,063.00	2,294.00	2,359.00	1,713.00	1,519.60
Weight of ashes, clinkers, and coal which fell through grate .... pounds..	48.00	59.00	67.00	684.00	156.00
Waste .... per cent..	2.33	2.58	2.84	40.00	10.30
Unburned fuel which fell through grate, pounds	16.00	20.00	22.50	....	....
Unburned fuel which fell through grate, per cent	.77	.87	.94	33.20	3.10
Clinkers in fuel .... pounds..	....	38.50	24.00	....	....
Clinkers in fuel .... per cent..	None.	1.24	1.02	....	3.50
Mean opening of damper (percentage of full opening) .... per cent..	100.00	100.00	100.00	50.00	60.00
Mean temperature of flue gases, degrees F	544.00	520.00	513.00	425.00	478.00
Mean pressure of draft in flue, inches of water	.30	.26	.234	.06	.10
Mean thickness of fire .... inches..	6.00	5.00	6.00	5.50	9.00
Mean opening of air inlets above fire per square foot of grate .... square feet..	None.	None.	None.	.002	.002
Coal burned per hour per square foot of grate .... pounds..	17.20	17.00	17.50	10.15	13.15
Coal burned per hour per square foot of heating surface .... pounds..	.35	.349	.36	.313	.315
Mean smoke production, on scale of 10...	Trace.	Trace.	Trace.	.50	.40
Evaporation of water from and at 212° F., per pound of coal .... pounds..	10.55	10.68	9.94	6.32	8.18
Fuel used .... kind..	Lump.	Lump.	Lump.	2¼ inch.	....
Chemical composition of coal, ultimate:					
Carbon .... per cent..	85.22	83.68	82.68	78.60	80.7
Hydrogen .... do....	4.31	4.46	4.65	4.58	5.66
Oxygen and nitrogen .... do....	5.79	3.19	3.98	2.61	3.55
Sulphur .... do....	.68	1.58	1.57	4.55	3.44

[a] Tested 1889.

Evaporative tests of Arkansas coals from mines of Western Coal and Mining Company compared with Pocahontas (West Virginia) lump coal.

	Pocahontas (W. Va.) lump.	Denning, Ark. (Spadra coal).	Jenny Lind, Ark. (Huntington coal).	Coal Hill (Spadra coal).[a]	Huntington, Huntington coal.[a]
Chemical composition of coal, proximate:					
Water .... per cent..	1.68	1.07	0.94	....	....
Volatile .... do....	17.45	11.21	13.64	....	....
Fixed carbon .... do....	75.99	78.01	76.73	....	....
Ash .... do....	4.20	8.13	7.12	....	....
Calorific power of coal, B. T. U., per pound, calculated..	14,760.00	14,750.00	14,744.00	12,500.00	11,400.00
Theoretical evaporative power from and at 212° F.	15.29	15.27	15.27	12.94	11.80
Total calorific power utilized, or efficiency, per cent	69.00	69.94	65.10	49.00	69.30
Capacity developed of boiler rating, per cent	129.60	133.06	124.17	....	....

[a] Tested 1889.

Description of boiler.—One return tubular steel boiler, 54-inch diameter, 16 feet long, with 36 4-inch flues. Heating surface: On shell, 166 square feet; of tubes, 564 square feet; total, 730 square feet. Plain setting, with "standard" rocking grates 3 by 5 feet, giving 15 square feet of grate surface. Percentage of opening, 27½. Area of chimney's cross section, 4.25 square feet; height of stack, 72½ feet.

DEVELOPMENT OF COAL MINING.

In this region extensive mining began first in the eastern part of the field along the Little Rock and Fort Smith Railroad in Franklin, Johnson, and Pope counties. Statistics of coal production were not reported prior to 1880, when the output for the State was 14,778 short tons.

Soon after the building of the St. Louis and San Francisco Railroad into the western part of the field, in 1883, mining development began in the Huntington, Hackett, and Bonanza regions.

The Missouri Pacific Railroad Company extended a branch later from Fort Smith to Greenwood, giving transportation to the Jenny Lind district.

Very recently the Memphis and Choctaw Railroad extended its main line eastward from Indian Territory to Little Rock and to Memphis, thus opening the markets to the Hartford district, also connecting with the St. Louis and San Francisco Railroad at Mansfield near the Huntington mines.

Still more recently a railroad has been projected from Fort Smith eastward into the middle of the field.

The following table is intended to show the development of the two principal coal beds by the leading companies in the Arkansas coal field:

Summary of mining operations.

Location.	Company.	Name of coal horizon.	Thickness.	Method of mining.
Jenny Lind, Ark.	Western Coal and Mining Co.	Huntington..	4 to 5 feet....	Shaft, room; electric machine.
Hackett, Ark...	Missouri and Arkansas Coal Co.	.....do	3 feet........	Shaft and slope, room.
Huntington, Ark.	Kansas and Texas Coal Co.	.....do	3 ft. 6 in. to 6 feet.	Shaft, slope, room.
Do	Prairie Creek Coal Co.	.....do	6 feet	Do.
Montana, Ark ..	Western Anthracite Coal Mining Co.	Spadra	3 feet	Shaft, room.
Spadra, Ark	Clark, McWilliams & Co.	.....do	3 ft. 4 in.....	Do.
Do	Spadra Anthracite Coal Co.	.....do	.....do	Do.
Johnson and Franklin counties, Ark.	Western Coal and Mining Co.	.....do	3 ft. 6 in.....	Shaft, room; machines used.
Secs. 21, 22, and 23, 7 N., 20 E., near Norristown and Shinn, Ark.	Mount Nebo Anthracite Coal Co.	.....do	3 ft. 4 in.....	Shaft, room.

Summary of coal openings.

Location.	Name of pit.	Coal horizon.	Thickness of coal. Ft.	Thickness of coal. in.	Remarks.
Sec. 9, 4 N., 29 W....	Harrisons	Huntington	1	8	
Sec. 12, 4 N., 30 W...	Bogwells	.....do	3	0	
Sec. 8, 4 N., 30 W....	Gibsons	.....do	2	9	Coal contains 2 shale strata.
Sec. 17, 4 N., 31 W...	Claiborne.....	.....do	5	2	Contains 4 shale partings.
Sec. 18, 4 N., 31 W...	Chasteens	.....do	3	7	Contains 2 shale bands.
Sec. 13, 4 N., 32 W., New Hartford.	Gwyn	.....do	5±		Shale 8-10 inches near base.
Sec. 2, 4 N., 32 W....	West	.....do	8±		Shale bed near middle.
Sec. 1, 4 N., 32 W....	Wininger	.....do	3	6±	
Huntington........	Huntington....	.....do	6	8±	2 thin shale bands 2 feet above base.
Sec. 18, 5 N., 31 W...	Pulliam	.....do	3	2	

Summary of coal openings—Continued.

Location.	Name of pit.	Coal horizon.	Thickness of coal. Ft.	in.	Remarks.
Sec. 7, 5 N., 31 W.	Powell's well	Huntington	6	2	Shale 3 feet 6 inches, 2 feet above base.
Sec. 8, 5 N., 31 W.	Martin	do	4±		Reported.
Sec. 19, 6 N., 30 W.	Page	do	2±		Bottom not seen.
Hackett City	Hackett City	do	3	0	Clean coal.
Greenwood	Greenwood shaft.	do	5	11	Shale 4 to 14 inches near middle.
Sec. 32, 7 N., 30 W.	McConnel	do	2	9±	1 thin shale in coal.
Sec. 18, 7 N., 30 W.	Carnall	do	3	10	1 thin shale below middle.
Jenny Lind	Rocquin and Reutzel's shaft.	do	5	0	Contains 2 to 3 inches of shale.
Do	Petty	do	5	0	2 inches shale in center of coal
Bonanza	Bugan shaft	do	4	4	5 to 6 inches shale at center.
Philpott	Philpott mine	do(?)	18–24		
Coal Hill	Stillwell & Co.'s mine.	Spadra	3	10	4 inches of shale near the middle.
Allister	Allister slope	do	3	10	Do.
Sec. 18, 9 N., 24 W.	Allen	do(?)	4	0	This shale divides coal into two benches.
Sec. 34, 10 N., 24 W.	Harkreaders	do			Do.
Near Spadra		do	3	0	Thin shale near center.
Sec. 23, 8 N., 24 W.		do	3	0	About 1 foot of shale divides coal.
Ouita	Ouita mines	do	2	6	

NORTH TEXAS COAL FIELD.

LOCATION AND BOUNDARIES.

The north Texas coal field extends from the south side of the Colorado River Valley between Lampasas and Concho counties northward to Red River in Montague County. It is nearly 250 miles in length, with an average width of about 45 miles, and has, therefore, an approximate area of 15,000 square miles.

The known coal-bearing strata, however, are much more limited, being confined to the central part, and are bounded upon either side by the outcrop of the highest and lowest of the three workable coal beds. The approximate location of the outcrops of these two workable coals is given on the map (Pl. XXVIII).

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The productive portion of the field is separated into a northern and a southern part by an arm of Cretaceous strata which extends from the main body of the Cretaceous northwestward along the watershed between the Colorado and Brazos rivers. The northern part, which is limited chiefly to the hydrographic basin of the Brazos River, is designated by the Texas Geological Survey the Brazos coal field, and the southern part, which is in the Colorado River Valley, the Colorado coal field. The belt of Cretaceous rocks separating the two parts of the Texas cold field is narrow and has no important bearing upon the economic conditions of the field, and will not be considered in this report.

The north Texas coal field is limited on the east by the Cretaceous rocks, which rest unconformably upon Coal Measures. At the south end of the field the Coal Measures lie unconformably upon the Mississippian (Lower Carboniferous), and are in part concealed by Cretaceous strata. Upon the west and northwest sides the Coal Measures are bounded and succeeded stratigraphically by the Permian.

Northward from the Texas coal field the upper part of the Coal Measures extend into Indian Territory and probably connect with the small coal field south of Ardmore in southeastern Chickasaw Nation. The coal-bearing strata, however, pass beneath the Cretaceous in the vicinity of Bowie, Montague County, Tex.

AGE OF THE COAL-BEARING ROCKS.

The coal-bearing rocks of the north Texas coal field belong to the Coal Measures or Pennsylvanian series of the Carboniferous. At the south end of the coal field these coal-bearing rocks rest unconformably upon strata of limestone and black shale, which belong to the Mississippian or Lower Carboniferous.[a]

The parting between the Carboniferous and Permian was mapped upon the evidence of fossils almost exclusively, and was recognized as being arbitrarily drawn.[b]

The highest formation of the Coal Measures either thins or passes beneath the Permian toward the north, suggesting an unconformability or overlap of the latter upon the former.

STRATIGRAPHY.

The Coal Measures of north Texas were separated by Mr. Cummins[c] into five divisions or groups, as follows: Albany, Cisco, Canyon, Strawn, Millsap.

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[a] A preliminary report upon the coal fields of the Colorado River, by Ralph S. Tarr: First Ann. Rept. Texas Geol. Survey, 1889, pp. 201-216.

[b] Report on the geology of northwestern Texas, W. F. Cummins: Second Ann. Rept. Texas Geol. Survey, 1890.

[c] Op. cit.

MILLSAP DIVISION.

This group of strata has not been recognized south of northern Erath County, though, according to the structure of the rocks, it should occur in the basin of Leon River in Comanche County. According to the Texas survey it thins southward and does not occur in the Colorado River Valley. North of Trinity River Valley in Wise County it is concealed by the overlap of Cretaceous rocks. The top of the formation includes coal bed No. 1, whose outcrop is located upon the map (Pl. XXVIII), and which is mined at Thurber, Gordon, Rock Creek, and Bridgeport. The strata of this group occur at the surface between the coal outcrop referred to above and the Cretaceous border. The base is not exposed, and much of the section, which has a thickness of about 1,000 feet, is concealed. The complete section was obtained by diamond drill, penetrating the strata at Thurber.

It is composed of blue and black shale, interstratified with occasional limestone and sandstone strata.

The deep wells at Gordon and Thurber produce gas and salt water, but no coals were encountered below coal No. 1.

STRAWN DIVISION.

This is composed of 19 separate members of sandstone and shale, making an aggregate thickness of 3,700 feet in the southern part of the field, where the members of the group rest unconformably upon the massive shale and limestone of the Mississippian, and in many cases are unconformable with regard to each other.

In the northern part of the field the aggregate thickness decreases to 950 feet. Coal is not known to occur in this division.

CANYON DIVISION.

This group is composed chiefly of limestone and shale, with local beds of sandstone and conglomerate. The thicker beds of limestone occur near the base and in the upper part of the series. The limestones are generally thick or massive and hard, making escarpments or outcroppings in prominent ledges. In the southern part of the field the group contains twelve separate members of limestone and shale and one conglomerate, making an aggregate in all of 800 feet of strata. Unlike the Strawn, this division increases in thickness northward. In the northern part of the field it contains 930 feet of strata. No coal is reported to occur in these rocks.

CISCO DIVISION.

There are nineteen different members in this group, each of which is found to be variable in lithologic nature. Some of the members contain limestone, shale, coal, and sandstone, and several contain conglomerate, while a few are composed almost entirely of limestone and shale. Throughout the section there are not fewer than twenty separate beds of limestone, which are usually thin. The shale as a whole is much thicker than all the other strata together, and the whole group aggregates about 800 feet from end to end of the field.

Several of the members which contain conglomerate rest upon eroded surfaces of lower beds, and in some instances have been found to overlap and displace beds of coal. The heterogeneous nature of this group of strata indicates many repeated changes in sedimentation. Several thin beds of coal have been recognized near the top and in the lower middle part of the group, besides two beds of workable thickness. These workable beds occur 200 and 300 feet above the base of the division.

ALBANY DIVISION.

The class of sediments making this group is generally a repetition of that found in the Canyon division. They are thick beds of limestone generally separated by shaly members.

According to Mr. Cummins's report the Albany division thins northward from 1,180 feet at the south end of the field to zero on the Brazos River.

It contains two shaly members which bear thin coal strata, none of which, however, have been found to exceed a few inches in thickness.

This group is succeeded by the Permian, which overlaps upon the Cisco division between Brazos and Red rivers.

STRUCTURE.

The structure of the Coal Measures in the North Texas coal field is simple monoclinal, with prevailing but slightly variable low dips toward the west and northwest. The dips are so low that it is practicable to estimate them only in feet per mile. The grade of the rocks in the northern part of the field, as determined in many separate localities, varies from 10 to 100 feet per mile, with a variation in direction from N. 15° W. to N. 75° W. The average grade is nearly 60 feet per mile, with an average bearing of N. 37° W. In the southern part of the field the average dip is estimated to be 40 feet per mile, with an average bearing of N. 65° W.

The general drainage and slope of the country is toward the southeast, opposite in direction to the dip of the rocks; but the grade is low, so that coal may be mined by shaft for a distance of several miles from its line of outcrop.

NUMBER AND EXTENT OF WORKABLE COAL BEDS.

There are three beds of coal in the north Texas coal field which are of sufficient thickness to be worked on a commercial scale. The lowest and highest of these, known as coal beds Nos. 1 and 7, respectively, are located at their outcrops by lines drawn upon the map, Pl XXVIII. The third workable coal, known as the Chaffin bed, occurs about 100 feet beneath bed No. 7. It is limited to a small area and is known to occur only in the vicinity of Lohn and Waldrip in the Colorado River Valley.

There are several coal beds, five of which have been located between beds No. 1 and No. 7, the lowest and highest that are workable in this field, and none of them except the local Chaffin seam is known to exceed a foot in thickness.

COAL BED NO. 1.

This is the lowest coal in the Texas field, and it occurs at the top of the Millsap formation, 1,000 feet above the base of the Coal Measures. It is mined at Thurber, Strawn, Rock Creek, and Bridgeport, all of which are located upon lines of railroad transportation. So far as it has been prospected or mined this coal bed is found to be continuous, though changing in thickness along its outcrop, through a distance of about 80 miles. The very low dip of the rocks and the general level surface of the country give an area of several hundred square miles of accessible coal.

In Wise County at its northernmost occurrence this bed varies from 14 to 26 inches in thickness, and in the Bridgeport Company's mines has an average of 18 inches. In western Parker County the bed is 18 to 26 inches in thickness, with an average of 22 inches in the mines now in operation on Rock Creek. At the Strawn mines, in southern Palo Pinto County, the coal is 26 inches, and in the Thurber mines at the southern end of the coal outcrop in northern Erath County it has an average thickness of 28 inches.

With very few exceptions both the roof and the floor of the coal are shale, which has sufficient hardness to admit of the coal being successfully mined.

The quality of this coal, according to the records of analyses Nos. 1 and 2 of the table, indicates that it is strongly bituminous, having a fuel ratio of 1.79. The percentages of ash and sulphur, however, are high, and would interfere with its successful use for other purposes than the production of steam and heat. The coal from the mines at Strawn and Thurber is reported to coke, but the quantities of ash and sulphur are in the way of its successful use for metallurgic purposes.

CHAFFIN COAL.

This bed occurs in the Cisco group of strata in the upper part of the Coal Measures, about 100 feet below bed No. 7. It is known to occur only at the Chaffin mine, 2 miles east of Waldrip, near the Colorado River, where it is 20 inches thick, and is overlain by limestone. It is reported that north of the river the horizon of this coal had been removed by erosion at the time of the deposition of the succeeding Coal Measures strata, and that its place is occupied by beds of con glomerate and sandstone.

The quality of the coal was considered to be higher in grade than is usually found in this region, but the thinness of the bed and its isolation from railroad transportation prevent its successful commercial development. The mine which was located upon it has been abandoned.

COAL BED NO. 7.

This coal occurs in the Cisco group, about 300 feet above its base. The outcrop of the coal has been traced through the field from the vicinity of Waldrip, in McCulloch County, to Bowie, in Montague County, a distance of 250 miles. The structure of this coal and its associated beds is practically the same as of coal bed No. 1, i. e., the rocks dip at very low angles toward the west and northwest, so that the coal may be mined successfully for a distance of several miles from the outcrop.

It has been prospected and mined for local use in all of the eight counties in which it occurs. The coal is exploited for commercial purposes only at the Vining mines in southern Coleman County. It was developed commercially near Bowie, Montague County, and Cisco, Eastland County, but the operations have ceased. It has a thickness varying from 12 to 42 inches, and except at one or two localities where the coal is thinnest it contains one and in places several layers of shale which require to be taken down and rejected in mining operations.

In the Bowie mines the coal is about 40 inches thick and is separated near the middle by a 6-inch bed of shale. From Bowie to Cisco, southwestward through Jack, Young, Stevens, and northern Eastland counties, the coal varies in thickness from 12 to 42 inches and contains one and sometimes several partings of shale. Between these points there is no railroad transportation and the coal is not mined except to a very limited extent for local consumption. In the vicinity of Cisco the coal is 33 inches thick, but is separated by two bands of shale 4 to 20 inches in thickness. An attempt was made to develop the coal at this point, but it proved a failure.

Between Cisco and Home Creek, near the Colorado River, the coal is broken by interbedded shale. On Home Creek, Bull Creek, and at the Vining mines in southern Coleman County, the coal varies from 28 to 34 inches in thickness, but usually contains a thin parting of shale.

COMPOSITION OF THE COALS.

The quality of the coal from bed No. 7 is relatively a little more bituminous than that of bed No. 1, as shown in the record numbers 3 to 7, inclusive. The volatile combustible matter is 4 to 9 per cent higher and the fixed carbon is 7 to 14 per cent less in this coal than in No. 1, which gives a lower fuel ratio. The average of analyses of bed No. 7 also shows higher percentages of water, ash, and sulphur.

The following table of analyses indicates the approximate qualities of the coals of the north Texas coal field.

The coal from the Vining mine at the south end of the field is reported to produce coke, but it has not been so utilized. The percentage of ash and sulphur would indicate that the coke could not be used successfully for metallurgic purposes.

The value of the coal depends upon the purposes to which it is suited and the public demand for it. Experimental tests to determine the uses to which the north Texas coals may be applied have not been reported, other than those for general steaming. They are sufficiently highly bituminous to produce illuminating gas. Most of the analyses, however, indicate too much sulphur in the coal for gas manufacture. Coals to be used in the manufacture of gas should also be coking coals. Demand requires that the coal mined in the north Texas coal field be used in producing steam, and practically all is so utilized in locomotives on Texas railroads, and for steam power in manufacturing establishments. Smaller quantities are also utilized for domestic fuel.

Table of proximate analyses of coals from the North Texas coal field.[a]

Number of analyses.	Name of coal bed.	Locality.	Moisture.	Volatile combustible matter.	Fixed carbon.	Ash.	Sulphur.	Fuel constituents.		Fuel ratio.
								Volatile combustible matter.	Fixed carbon.	
1	No. 1	Bridgeport, Wise County	2.00	31.47	56.32	8.15	2.06	35.84	64.16	1.79
2	No. 1	Thurber, Erath County	.88	31.57	56.81	8.93	1.47	35.72	64.28	1.79
3	No. 7	Thurber shaft near Bowie, Montague County	2.30	34.48	61.28	.60	1.14	36.00	64.00	1.77
4	No. 7	Vining mine, southern Coleman County	4.05	40.40	46.75	8.80	2.87	46.35	53.65	1.15
5	No. 7	Bull Creek, Coleman County	10.40	35.94	49.46	4.19	1.53	42.08	57.92	1.37
6	No. 7	1¼ miles southwest of Rockwood, southern Coleman County.	3.23	37.54	42.80	16.40	3.67	46.73	53.27	1.14
7	No. 7	Waldrip, McCulloch County	4.55	38.50	44.80	12.14	7.96	46.21	53.79	1.16

[a] All analyses except No. 3, which is reported by the Vining Mining Company, were made by the Texas Geological Survey in 1890.

SUMMARY OF MINING OPERATIONS.

Station.	Company.	Mine.	Location	Name of coal bed.	Thickness.	Method of mining.
Bridgeport ..	Bridgeport Coal Co.	Shaft No. 1, 56 feet.	½ mile west of Bridgeport.	No. 1, or Bridgeport.	14 to 22 in.	Longwall "advancing."
Do.......	.....do	Shaft No. 2..	1 mile northwest of Bridgeport.	.....do	.....do	Do.
Rock Creek station.	Texas Coal and Fuel Co.	Shafts	Rock Creek station.	No. 1	22 in. (average).	Do.
Strawn	Strawn Coal Mining Co.	Shaft, 332 feet.	Strawn........	.....do	26 in......	Do.
Thurber	Texas Coal Co	4 shafts, 100 to 200 feet.	Thurber vicinity.	.....do	28 in. (average).	Do.
Coleman	Vining Coal Co	Shaft, 97 feet.	Southern Coleman County.	No. 7	28 in......	Do.

ARDMORE COAL DISTRICT, INDIAN TERRITORY.

A small area of coal-bearing strata is known to occur in the region south of Ardmore in the Chickasaw Nation, Indian Territory. It is separated from the coal-bearing rocks of the Indian Territory coal field by the uplift of older rocks in the Arbuckle Mountains and from the coal-bearing strata of the north Texas coal field by a westward projection of Lower Cretaceous strata in the valley of Red River.

The age of the Ardmore coal-bearing rocks is not positively known. Their position in the section, however, would indicate that they are high in the Coal Measures section.

The rocks in the Ardmore region are extremely folded, and faults are known to occur in them. The rocks containing the coal are tilted at considerable angles toward the northeast.

Only one coal bed has been reported to occur in this field, and its outcrop extends from the vicinity of Ardmore southeastward toward the Cretaceous border 10 to 15 miles distant. The coal bed is reported to occur in two benches 20 to 40 inches thick, separated by about 40 inches of shale. The coal is overlain by a bed of limestone. This coal was exploited to a considerable extent and shipped on a commercial scale during several years both preceding and following 1890, but the mining operations have since been abandoned. Recently Messrs. E. F. Ensworth and Mike Gorman have begun developing the coal, but their output is as yet quite small.

DISTRIBUTION.

LOCATION AND CHARACTER OF MARKETS.

The coal from this field finds a market chiefly toward the south. It comes in competition with the Western Interior field in Kansas and Missouri and with the Eastern Interior and Appalachian fields along the Mississippi River. An important and growing factor in the development of this field is felt in the competition offered by the petroleum of southern Texas and California, which is being largely introduced as fuel. The extent to which this liquid fuel will replace coal can not at present be estimated, but its use will doubtless be extensive, particularly as locomotive fuel on the southern transcontinental lines from middle Texas westward to the Pacific coast. The semibituminous and anthracite coal of the Arkansas field, on account of its superior quality as a domestic fuel, finds a ready market in States to the northward, going as far as Kansas City and supplying much of the demand for domestic fuel at intermediate points. Some of the output of the Indian Territory field also goes north into Kansas and Missouri. A large portion supplies the markets in southern Arkansas and Louisiana, and a still larger amount goes south and southwest to the Texas markets. A large part of the output from the northern Texas field is used for locomotive fuel by the various railroads of southern and central Texas. With the exception of a small field at Eagle Pass, the Southern Pacific Railroad is dependent upon the Texas field for fuel entirely to the Pacific coast.

The following table indicates in a general way the proportion of the product from the southwestern field consumed by railway companies, manufacturing establishments, and for domestic fuel. Since reports were not obtained from all the producers, the figures given in this table are not exact. It is assumed that the same proportionate distribution applies to all mines as to those from which reports were obtained.

Production and distribution of product of the Southwestern coal field in 1900.

State.	Production.	Value at mines.	Average value per ton.	Railroad fuel.	
				Quantity.	Per cent.
	Short tons.			*Short tons.*	
Indian Territory	1, 922, 298	$2, 788, 124	$1. 45	1, 095, 710	57
Arkansas	1, 447, 945	1, 653, 618	1. 14	434, 384	30
Texas (north)	536, 030	982, 816	1. 83	....	......
Total	3, 906, 273	5, 424, 558	1. 39	....	......

State.	Steamboat fuel.		Manufacturing fuel.		Domestic fuel.		Made into coke.	
	Quantity.	Per cent.	Quantity.	Per cent.	Quantity.	Per cent.	Quantity.	Per cent.
			Short tons.		*Short tons.*		*Short tons.*	
Indian Territory	....	....	538, 243	28	231, 392	12	56, 953	3
Arkansas	....	....	275, 109	19	738, 452	51	....	....
Texas (north)	....	....	....	....	....	....	....	....
Total	....	....	....	....	....	....	56, 953	1

Relation of production to capacity of mines for the Southwestern coal field in 1900.

State.	Number counties producing coal.	Number commercial mines.	Production, 1900.	Estimated capacity of mines, 1900.	Ratio of production to capacity.	Per cent of mines reporting prospective increase of capacity.
			Short tons.	*Short tons.*		
Indian Territory	....	33	1,922,298	3,253,792	0.59	67
Arkansas	5	28	1,447,945	1,739,822	.83	80
Texas (north)	5	6	536,030	....	....	....

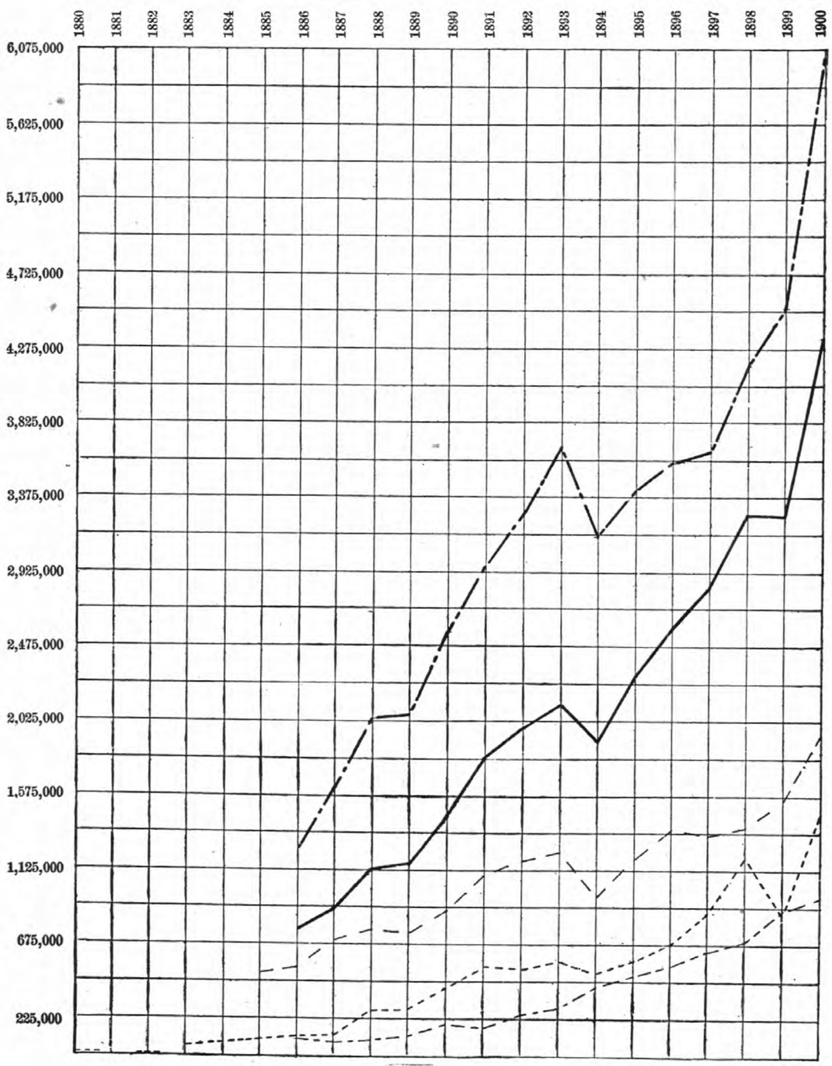

FIG. 35.—Production and value of coal in Southwestern field from 1880 to 1900.

------- Arkansas. — — — — — Indian Territory. —·—·—·— Texas. ▬▬▬▬ Total production. ———–——– Total value.

Scale { 225,000 tons to the square. $225,000 to the square.

Development of the Southwestern coal field by decennial periods.

State.	1880.			1890.		
	Production.	Value.	Average price per ton.	Production.	Value.	Average price per ton.
	Short tons.			*Short tons.*		
Indian Territory				869, 229	$1, 579, 188	$1. 81
Arkansas	14, 778	$33, 535	$2. 27	399, 888	514, 595	1. 29
Texas (north)						

State.	Increase of 1890 over 1880.			
	Product.	Per cent.	Value.	Per cent.
	Short tons.		*Short tons.*	
Indian Territory	869, 229		$1, 579, 188	
Arkansas	385, 110	2, 605	481, 060	1, 435
Texas (north)				

State.	1900.			Increase of 1900 over 1890.			
	Production.	Value.	Average price per ton.	Product.	Per cent.	Value.	Per cent.
	Short tons.			*Short tons.*			
Indian Territory	1, 922, 298	$2, 788, 124	$1. 45	1, 053, 069	121	$1, 208, 936	77
Arkansas	1, 447, 945	1, 653, 618	1. 14	1, 048, 057	262	1, 139, 023	221
Texas (north)	536, 030	982, 816	1. 83				

TRANSPORTATION FACILITIES.

Shipments of coal from this field to markets are entirely by rail and the development in different parts of the field has been directly dependent on the building of railroads. Four roads reach the Indian Territory field and transport its product direct to market or to railroad centers for further distribution. The Missouri, Kansas and Texas and the St. Louis and San Francisco railroads supply the markets of the larger cities in central Texas, while the Kansas City Southern extends to the Gulf. The Choctaw, Oklahoma and Gulf railroad furnishes an outlet for the coal eastward as far as East Tennessee and westward through Oklahoma. Coal from the Arkansas field goes north and south over the Kansas City Southern, the St. Louis and San Francisco, and the St. Louis, Iron Mountain and Southern railroads. The markets east and west of this field are supplied over the Memphis and Choctaw road. The north Texas coal field is intersected by six railroads, five of which transport and distribute a considerable amount of coal. These are the Gulf, Colorado and Santa Fe; Texas and Pacific; Weatherford, Mineral Wells and Northwestern; Chicago, Rock Island and Texas, and the Fort Worth and Denver City railroads. As stated above, a large proportion of the output from this field is used by these roads as locomotive fuel.

THE ROCKY MOUNTAIN COAL FIELDS

BY

L. S. STORRS

CONTENTS.

ILLUSTRATIONS.

THE ROCKY MOUNTAIN COAL FIELDS.

By L. S. Storrs.

GENERAL RELATIONS.

LOCATION AND EXTENT.

The coal fields of the Rocky Mountain region occupy a belt along the eastern base of the main range, extending southward from the Canadian boundary fully 1,000 miles, through Montana, Wyoming, Colorado, and New Mexico. The coal-bearing formations are not continuous throughout this belt, but occupy about 60 per cent of the distance. Another less extensive belt of coal fields occurs along the western base of the Rocky Mountain range in Wyoming, Utah, Colorado, and New Mexico. Between these two belts, in the Park region, are numerous isolated basins, in most of which the strata are so much disturbed that the coal is mined with difficulty. In addition to these fields, in which the coal is generally bituminous, the coal-bearing formations extend eastward from the mountains and underlie large areas of the plains in Montana, Wyoming, and the Dakotas. In these fields the coal is generally a lignite, and therefore at present chiefly important as a source of fuel for local use.

The magnitude of the aggregate area of these fields is at yet scarcely appreciated. Owing to the lack of geologic information regarding much of this region, the areas of many of the fields, as well as the amount of coal which they contain, are known only approximately. Their outlines as shown on the accompanying maps, Pls. XXIX and XXX, are based on the best available information, much of which is as yet unpublished.

According to the latest estimates the areas of the coal-bearing formations in the six States and one Territory of the Rocky Mountain region are as follows:

Areas of coal-bearing formations in the Rocky Mountain region.

State or Territory.	Anthracite, bituminous, and lignitic-bituminous coal.	Lignite.
	Square miles.	*Square miles.*
Montana	13,000	19,000
North Dakota	....	24,000
South Dakota	120	4,500
Wyoming	7,500	9,000
Utah	2,000	....
Colorado	18,100	....
New Mexico	2,890	....
Total	43,610	56,500

It is at present impossible to make any accurate estimate of the proportion of this area which contains workable coal, much less of the tonnage of available fuel, but such estimates have been made for the Colorado fields, which are better known than those of the other States. A conservative estimate places the workable area in that State at about 50 per cent of the total area given above as occupied by the coal-bearing formations, and the available coal is estimated at 33,897,800,000 tons.

AGE OF THE COAL.

Practically all the coal of the Rocky Mountain region is contained in beds of Cretaceous age, and a large proportion is found in the Laramie formation. The following table shows the accepted classification of the Cretaceous formations of this region:


SOUTHERN
ROCKY MOUNTAIN
COAL FIELDS
Showing
Cretaceous coal-bearing formations
BY L.S. STORRS
Scale
25 0 25 50 MILES
LEGEND
Anthracite, bituminous and lignitic-bituminous coals
Principal coal mines
COLORADO
NEW MEXICO
YAMPA FIELD
WASATCH FIELD
HENRY MTS. FIELD
LA PLATA FIELD
RATON FIELD
GALLUP FIELD
MOUNT TAYLOR FIELD
JARILLOSA AREA
CARTHAGE AREAS
CERRILLOS AREA
TEJON AREA
NORTH PARK
TONGUE MESA
CANYON CITY
JULIUS BIEN & CO. LITH. N.Y.

Cretaceous formations in the Rocky Mountain region.

	General.		Black Hills.	Montana.		Western Wyoming and northern Utah.	Central Colorado.	Southern Colorado.	Southwestern Colorado.	Canada.		
Cret.?				Livingstone.	Livingstone.		Denver, Arapahoe.			Laramie.	Paskapso.	Porcupine Hills, Willow Creek.
Upper Cretaceous.	Laramie.	Laramie.	Laramie.	Laramie.	Laramie.	Laramie.	Laramie.	Laramie.	Laramie?		Edmonton.	St. Mary River.
	Montana.	Fox Hills.	Fox Hills.	Yellowstone	Montana.	Montana.	Montana.	Trinidad.	Lewis.	Montana.	Fox Hills.	
		Fort Pierre.[a]	Pierre.					Pierre.	Mesaverde.		Pierre.	
					Eagle.				Mancos.	Belly River.[c]	Belly River (Dunvegan?)[d]	
	Colorado.	Niobrara.	Niobrara.		Colorado.	Colorado.	Colorado.	Niobrara {Apishapa. Timpas.		Colorado.	Niobrora.	
		Fort Benton[a]	Benton.					Benton {Carlile. Greenhorn. Graneros.			Benton.	
	Dakota.	Dakota.	Dakota.		Dakota.	Bear River, Dakota.	Dakota.	Dakota.	Dakota.	Dakota.	Dakota.	Mill Creek.
Lower Cretaceous.			Lakota.	Cascade.[b]	Cascade.[b]					Kootanie.	Kootanie.	

[a] Usually shortened to Pierre and Benton.
[b] Correlated with the Kootanie of Canada.
[c] Locally interpolated between the Colorado and Montana, like its probable equivalent, the Eagle formation.
[d] Position uncertain, but believed by the Canadian geologists to belong somewhere within the Colorado.

The Cretaceous formations of New Mexico are the same as those of Colorado, with the addition of some outliers of the Lower Cretaceous Comanche series in the eastern part of the Territory.

CHEMICAL ANALYSES.

In the compilation of the accompanying tables of analyses the writer has made use of the articles by Mr. R. C. Hills on the coal fields of Colorado and by Prof. W. C. Knight on the coal fields of Wyoming, in previous volumes of Mineral Resources.

In the classification of the coals the writer has attempted to outline a variation from the accepted system of classification, in order to differentiate, if possible, the great mass of Rocky Mountain coals which chemically are closely related to the true lignites but which are in reality of a much higher fuel value. It is to be desired that some system of classification will be proposed that will do away with the old one, which is so confusing as applied to the Cretaceous coals.

Analyses of coals from the Rocky Mountain fields.

COLORADO.

Field.	Character of coal.	Water.	Volatile combustible matter.	Fixed carbon.	Ash.	Fuel ratio.
Raton	Coking	0.75	31.13	57.07	11.05	1.80
Do	do	.52	32.18	58.40	8.90	1.81
Do	Semicoking	1.89	35.00	57.51	5.33	1.64
Do	Bituminous	2.06	38.15	52.04	7.75	1.36
Do	do	4.88	36.25	53.57	5.30	1.48
Do	do	6.54	36.97	48.52	7.97	1.31
Canyon City	Semibituminous	6.21	31.32	52.47	11.10	1.65
Do	do	7.26	35.70	53.04	4.00	1.49
South Platte	Lignite	22.95	28.64	43.31	5.10	1.51
Do	do	21.37	33.38	40.31	4.95	1.21
South Park	Bituminous	6.30	33.81	58.61	1.28	1.73
Do	do	7.81	38.72	49.40	4.70	1.28
North Park	Lignite	15.20	33.30	48.00	3.50	1.44
Do	do	12.25	34.75	38.75	14.25	1.12
La Plata	Coking	.82	37.25	55.72	6.05	1.50
Do	do	1.07	34.61	52.01	12.25	1.50
Do	Bituminous	4.10	37.72	54.46	3.75	1.44
Tongue Mesa	Lignite	15.67	37.79	36.44	10.10	.94
Grand River	Coking	1.79	37.23	56.93	4.05	1.52
Do	do	.56	22.42	71.31	5.70	3.18
Do	do	.60	21.42	70.02	7.85	3.27
Do	Anthracite	.59	6.59	88.82	4.00	13.47
Do	do	.58	6.39	87.23	7.05	13.65
Do	do	.72	7.62	87.51	4.15	11.48

WYOMING.

Field.	Character of coal.	Water.	Volatile combustible matter.	Fixed carbon.	Ash.	Fuel ratio.
Hams Fork	Lignite	13.88	38.80	42.72	4.60	1.10
Do	Lignitic	7.75	35.10	50.60	6.55	1.44
Black Hills	Bituminous	8.58	44.36	37.12	9.95	.84
Do	Semicoking	5.94	40.36	39.90	15.80	.99
Powder River	Lignite	10.52	37.92	38.54	13.02	1.02
Do	do	13.55	35.05	45.30	6.10	1.29
Rock Springs	Lignitic	4.25	39.00	54.70	2.05	1.40


NORTHERN
ROCKY MOUNTAIN
COAL FIELDS
Showing
Cretaceous coal-bearing formations
BY L. S. STORRS
Scale
25 0 25 50 MILES
LEGEND
Semi-bituminous, bituminous and lignitic-bituminous coals
Lignite
Principal coal mines
MONTANA
WYOMING
GREAT FALLS FIELD
JUDITH BASIN FIELD
CLARK FORK FIELD
BULL MTS. FIELD
YELLOWSTONE FIELD
TRAIL CREEK FIELD
ROCKY FORK
RUBY VALLEY FIELD
WEST GALLATIN FIELD
CINNABAR FIELD
BIGHORN BASIN FIELD
YELLOWSTONE NATIONAL PARK
YELLOWSTONE FOREST RESERVE
TETON FOREST RESERVE
WIND RIVER FIELD
CASPER
HANNA FIELD
CARBON FIELD
RAWLINS FIELD
ROCK SPRINGS FIELD
HAMS FORK FIELD
SUBLETTE FIELD
HENRYS FORK
DAWSON
CUSTER
FERGUS
MEAGHER
JEFFERSON
MADISON
GALLATIN
PARK
SWEET GRASS
CARBON
CROW IND. RES.
NORTHERN CHEYENNE IND. RES.
SHERIDAN
BIGHORN
JOHNSON
FREMONT
NATRONA
SWEETWATER
UINTA
BINGHAM
BANNOCK
FORT HALL IND. RES.
LEWIS AND CLARKE FOREST RESERVE
Helena
Great Falls
Benton
Choteau
Lewistown
Billings
Big Timber
Bozeman
Livingston
Red Lodge
Bridger
Gebo
Butte
Anaconda
Boulder
Deerlodge
Dillon
Virginia City
Sheridan
Buffalo
Lander
Casper
Rawlins
Hanna
Carbon
Rock Springs
Green River
Black Butte
Diamondville
Evanston
Almy
Blackfoot
Pocatello
St. Anthony
NORTHERN PACIFIC R.R.
UNION PACIFIC R.R.
OREGON SHORT LINE R.R.
BIGHORN MTS.
WIND RIVER MTS.
OWL CREEK MTS.
MEDICINE BOW MTS.
JULIUS BIEN & CO. LITH. N.Y.

Analyses of coals from the Rocky Mountain fields—Continued.

WYOMING—Continued.

Field.	Character of coal.	Water.	Volatile combustible matter.	Fixed carbon.	Ash.	Fuel. ratio.
Rock Springs	Lignitic	6.98	34.42	52.60	2.00	1.53
Do	do	7.70	37.80	52.90	1.60	1.40
Carbon	Semibituminous	6.13	42.37	46.05	5.45	1.09
Do	Lignite	11.70	41.41	39.65	7.24	.96
Bighorn	Lignitic	6.40	38.30	49.72	5.50	1.30
Do	do	7.20	37.80	48.01	6.99	1.27
Do	Lignite	10.58	28.73	42.49	7.20	1.10
Sheridan	do	13.05	37.55	44.70	4.70	1.19
NEW MEXICO.						
Carthage	Coking	1.28	36.02	51.46	11.24	1.43
Whiteoaks	Bituminous	9.13	38.45	49.43	2.99	1.29
Do	do	6.66	40.13	45.56	7.65	1.14
Do	do	2.35	35.53	50.85	11.88	1.43
Cerrillos	Anthracite	2.90	3.18	88.91	5.21	27.96
Gallup	Lignitic	12.14	32.81	47.63	7.42	1.45
MONTANA.						
Clarks Fork (upper measures).	Lignitic	6.53	38.22	48.33	6.92	1.26
Do	do	6.86	37.54	47.07	8.53	1.25
Do	do	6.02	37.30	46.28	10.40	1.24
Clarks Fork (lower measures).	do	4.42	32.36	44.19	19.03	1.37
Do	do	5.47	34.20	43.95	16.38	1.29
Yellowstone	Coking	1.02	38.01	48.20	11.87	1.27
Do	Semicoking	2.14	37.01	55.54	5.31	1.50
Horr	Coking	.67	30.90	57.56	10.87	1.86
Do	Semianthracite	1.02	18.77	75.87	4.34	4.04
Trail Creek	Lignitic	10.51	31.87	49.22	8.57	1.54
Do	do	7.70	37.11	45.00	10.19	1.21
Belt Mountain	Semicoking	3.68	25.43	58.05	11.71	2.28
Bull Mountains	Dry lignite	7.84	42.71	42.65	6.80	9.91
Do	do	6.42	38.54	49.94	5.10	1.30
Eastern	Lignite	21.11	28.55	44.98	5.01	1.58

COAL TESTS.

The following is a summary of a series of detailed tests conducted by the Northern Pacific Railway Company for the purpose of determining the relative value of the various coals that are at present used or may be required.

Each test was made on from 30 to 40 tons of coal, all being conducted under exactly similar conditions. The tests were very complete, including a determination of the theoretical efficiency of the coals from an ultimate analysis, a stationary boiler test, and tests on both mogul and consolidation engines hauling a given tonnage and operated both ways over a division that included the maximum as well as the minimum grades.

The results include the calculated percentage values of the various fuels referred to the standard. One of the coals from the Youghiogheny district of Pennsylvania is taken as the standard.

This summary is of especial interest, as it shows the relative values of the coals of the eastern portion of the United States as compared with those of the Rocky Mountain region.

In the preparation of the table the name of the mine has not been given, it being deemed sufficient to give the district from which the coal was obtained.

Practical tests of Rocky Mountain coals.

District.	Character of coal.	Theoretical.			Stationary boiler test.		
		Calorific power (B.T.U. per pound.)	Evaporation from and at 212°.	Relative efficiency.	Actual evaporation at working temperature and pressure.	Evaporation from and at 212°.	Relative efficiency.
			Pounds.	*Per ct.*	*Pounds.*	*Pounds.*	*Per ct.*
Youghiogheny, Pa	Bituminous	13,860	14.351	100	6.83	8.17	100
Do	do	14,053	14.551	101	6.99	8.37	102
West Virginia	do	14,054	14.552	101.4	6.57	7.90	104.3
Moon Ridge	do	13,888	14.380	99.9	6.83	8.21	108.6
Arnold Ridge	Coking	13,766	14.253	98.9	6.85	8.20	108.7
Shenango, Pa	Bituminous	13,284	13.754	96.4	5.87	7.07	93.5
Hocking Valley	do	11,829	12.248	89.7	5.73	6.87	92.1
Horr, Mont	Coking	12,984	13.443	93	6.18	7.40	100.7
Livingston-Bozeman, Mont.	Bituminous	12,113	12.542	88.4	5.30	6.34	84.6
Rocky Fork (Rock Creek district).	Semibituminous	10,553	10.926	80	5.82	6.97	94.6
Do	do	10,793	11.175	81.2	5.79	6.93	93.4
Rocky Fork (Bear Creek district).	do	10,434	10.802	81.1	5.30	6.36	86.1
Trail Creek	do				5.79	6.88	93.1
Clarks Fork, Mont	Lignitic	10,545	10.918	79.7	4.82	5.79	78.3
Miles City, Mont	Lignitic of plains	7,721	7.994		3.60	4.32	60.5
Rock Springs, Wyo	Semibituminous	11,861	12.281	89.7	5.90	7.11	95.6
Carbon	do	11,750	12.166	85.6	5.23	6.27	84.2
Roslyn, Wash	do	12,382	12.821	90	5.66	6.77	90.5
Wilkinson, Wash	Coking	12,706	13.156	91.1	5.76	6.91	92.6

Practical tests of Rocky Mountain coals—Continued.

District.	Character of coal.	Mogul locomotive test.			Consolidation locomotive test.		
		Actual evaporation at working temperature and pressure.	Evaporation from and at 212°.	Relative efficiency.	Actual evaporation at working temperature and pressure.	Evaporation from and at 212°.	Relative efficiency.
		Pounds.	*Pounds.*	*Per ct.*	*Pounds.*	*Pounds.*	*Per ct.*
Youghiogheny, Pa	Bituminous	6.90	8.35	100	6.94	8.42	100
Do	do	7.42	8.98	107.5	7.63	9.27	110.1
West Virginia	do	5.96	7.30	94	8	9.71	106.6
Moon Ridge	do	5.77	7.08	91.2	7.47	9.07	99.5
Arnold Ridge	Coking	6.62	8.06	103.8	7.59	9.19	100.8
Shenango, Pa	Bituminous	5.56	6.81	87.7	7.74	8.21	90.1
Hocking Valley	do	5.08	6.21	80	5.96	7.21	79.1
Horr, Mont	Coking				5.67	6.81	74.7
Livingston-Bozeman, Mont.	Bituminous	5.15	6.27	80.8	5.86	7.14	78.3
Rocky Fork (Rock Creek district).	Semibituminous	4.97	6.06	78	5.52	6.74	74
Do	do	5.30	6.47	83.2	5.57	6.80	74.5
Rocky Fork (Bear Creek district).	do	4.57	5.55	71.5	5.65	6.88	75.5
Trail Creek	do	5.14	6.25	80.5	5.02	6.16	67.6
Clarks Fork, Mont	Lignitic	4.70	5.73	73.8	5.37	6.54	71.8
Miles City, Mont	Lignitic of plains						
Rock Springs, Wyo	Semibituminous	5.29	6.46	83.5	5.96	7.24	79.5
Carbon	do	3.62	4.43	57	6.03	7.34	80.5
Roslyn, Wash	do	4.99	6.08	78.3	6.02	7.33	80.4
Wilkinson, Wash	Coking	4.62	5.62	72.4	6.47	7.88	86.5

The history of the development of the various coal fields of the Rocky Mountains is essentially the history of the general development of the region, which has no parallel elsewhere in the United States.

Throughout this area the development of the coal-mining industry has kept pace with the demands created by the general advancement of the region tributary to the several fields; and in no case has any one field been called upon for a tonnage within a quarter of its possibilities. At the present time the great activity in all branches of trade has made a demand on the producing fields which has been hard to meet, chiefly because of the scarcity of miners and laborers of all kinds.

COLORADO.

For the following account of the various fields of Colorado, Utah, southern Wyoming, and New Mexico the writer is greatly indebted to Mr. R. C. Hills, geologist of the Colorado Fuel and Iron Company of Denver, whose papers, The Coal Fields of Colorado[a] and The

[a] Mineral Resources of the United States for 1892, p. 319 et seq.

Coal Fields of the South Central Rocky Mountains,[a] prepared for presentation to the Federated Institute of Great Britain, have been used with the author's permission.

As already stated, the coal-bearing rocks of Colorado are confined to the Upper Cretaceous, and with but few exceptions to the Laramie formation. Areas of coal-bearing formations are found along both the eastern and western flanks of the Rocky Mountains, with two smaller fields in the park region immediately back of the Front Range, between that and the main range. For convenience the fields have been divided into three groups, the eastern, park, and western, the fields of each group being separated by areas of great elevation and erosion. The fields of the eastern group are the Raton, Canyon City, and South Platte; those of the park region, Middle Park and Como; those of the western group, the Yampa, Grand River, and La Plata, with several small areas separated from the main fields by erosion.

The coal fields of Colorado contain every variety of coal from the typical lignite to the equally typical anthracite. The area of the latter, however, is very limited, probably not exceeding 8 square miles.

The fields of the eastern group are the more accessible to the principal markets, the product of the western group being subject to the higher freight rates incident to the haul over the main range in reaching the large markets of eastern Colorado and the prairie States.

The fields of this State have been more thoroughly explored than those of any of the other States of the Rocky Mountain region, owing to the aggressive policy of the Colorado Fuel and Iron Company. This exploration has demonstrated the superiority of the Colorado coal fields over those of the other States in the Rocky Mountain region as to the size of the fields, their available tonnage, and the character of the coal itself.

RATON FIELD.

This field takes its name from the Raton Mountains, which are included within its limits. Part of the field is situated in Colorado and part in New Mexico, but only that portion which is in Colorado is here considered.

The field is bounded on the south by the Colorado–New Mexico line, and extends eastward along this line from the base of the Front Range to the plains. This range forms the western edge of the field, and the coal-bearing measures extend northward along its base a distance of 45 miles, reaching out into the plains an average of 32 miles throughout this length. The southern portion of the field is drained by the Purgatory River and its branches; the Huerfano River drains the northern end. These streams are located very near the southern and northern ends of the field, respectively.

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[a] In manuscript.

As yet the productive area of the field is limited to the eastern edge, that being the most readily accessible. For freight-tariff purposes it is divided into two districts: The southern or Trinidad district is located near the southeast corner of the field and includes the mines of Las Animas County; the northern or Walsenburg district includes the mines of Huerfano County. Besides these districts there is a very important area, at present nonproducing, which constitutes by far the largest portion of the field. A part of this area will become productive upon the completion of a railroad line that is now being constructed along the Purgatory River westward from Trinidad.

Immediately below the lowest coal is a bed of massive sandstone 90 to 120 feet thick. This is the uppermost member of the Trinidad formation, and is very persistent throughout the entire area. The thickness of the Laramie in this field varies from 3,000 feet, as exposed immediately under the basalt flow of the Raton Mountains, to 4,500 feet on the Cuchara River. The Laramie strata are divided into two groups, upper and lower, each of which contains throughout the entire extent of the field at least one coal bed of workable thickness. The individual seams, however, vary greatly in character, and a seam which is productive at one point may be worthless a short distance away. The two groups are separated by a barren zone of about 700 feet.

The main structural features of the field were determined by the post-Cretaceous revolution, at which time the Sangre de Cristo and Wet Mountain ranges were elevated. By this disturbance the strata along the western border were tilted up along the eastern base of the Sangre de Cristo Range, while on the opposite side of the field a broad anticline was produced. A second epoch of disturbance coincided with the period of eruptive activity. As the result of these movements the strata along the western border are tilted from 25° to 85° to the east and those along the eastern border from 3° to 17° toward the west, while in a broad belt extending north and south through the middle of the field they are nearly horizontal. The fault displacements produced by these disturbances are in places very numerous and in many cases of some magnitude, the largest ranging from 70 to 80 feet. These faults, however, appear to have no connection with the eruptive bodies, as in many cases mining operations have been extended through an intrusive dike without change of level.

There are numerous masses of eruptive rocks within the limits of the field, all of which have played an important part in the alteration of the various coal beds. The most noticeable of these are the Spanish Peaks and the attendant series of dikes situated at about the center of the western border, Silver Mountain, in the northwest corner, and the great overflow of the Raton Mountains along the southern border. The attendant dikes and interbedded sheets have cut through the productive measures, and in several instances the sheets have entirely destroyed the coal or altered it into a hard columnar coke which has no marketable value.

In this field, more than in any other in the State, there is a noticeable lack of uniformity in the thickness of the individual coal beds. The most persistent is the lowest, which is also the only one that can be identified in different parts of the field with any degree of certainty. Extensive exploration of the field, both on the surface and by diamond drill, has developed the presence of about 40 coal beds in the entire section. Of these, five are usually of a workable thickness, two or three in the lower measures and two in the upper.[a]

The beds worked in the Trinidad district are confined to the lower series, although in the northern part of the district the upper group contains two workable seams. In the southern part of the district the producing mines have from 4 to 8 feet of coal. The beds here have a slight inclination, which gradually increases toward the north, becoming as high as 15° in places near the northern end of the district.

In the southern portion of the Walsenburg district three beds are worked, their total thickness being about 16 feet. Numerous dikes have been encountered in mining operations in this portion of the district, entailing considerable expense in the "dead work" necessary to drive entries through them. This is offset to a great extent by the superiority of the product from that portion of the bed affected by the intrusion. These mines encounter water at a distance of about 1,000 feet from the outcrop. The mines in the northern portion of the district are operated upon 4 beds, the total thickness of which is about 9 feet. These mines, being operated below the level of the Cuchara River, are in "wet ground." The strata in this district have an inclination of 3° to 8° toward the southwest.

Aside from this eastern edge, the measures have been thoroughly explored at only two other points, both in Las Animas County, on the drainage of the Purgatory River. The first embraces the highly inclined measures of the lower series along the western border, where 2 beds of excellent coking coal have been opened up at intervals from the State line north to the center of this side of the field. The second district lies about 12 miles east of the first, where 2 workable beds of the upper series outcrop within a short distance of the Purgatory River. These seams have only very slight inclination. The beds of the lower series have not been tested at this point, but they will doubtless be found to contain a workable thickness of coal, which can be reached by shafts from 600 to 1,000 feet deep.

The coal of the northern district is entirely of the semicoking variety known as "domestic," though the finer sizes make an excellent steam

[a] Mr. Hills has divided the coal beds of this field into groups, but owing to the limited space allotted to this article the discussion of these is omitted. The reader is referred to folios Nos. 58, 68, and 71 of the Geologic Atlas of the United States, which include the region covered by the eastern and southern portions of the field.

coal, which is largely used in the accessible territory. There is a limited quantity of this kind of coal in the southern district, but the bulk of the product is a true coking coal. The transition from one variety to the other is very gradual, and hence there is an area through the center of the field which produces a coal that cokes too strongly for domestic purposes, yet does not produce a desirable metallurgic coke in the ordinary beehive oven. The coal of the upper series of beds is better adapted for coke making than that of the lower series, and with proper manipulation a most excellent metallurgic fuel can be produced.

A large portion of the domestic coal and a little of the steam coal reaches the markets of Kansas and Nebraska, the rest being consumed in Colorado. The principal consumers of the coke and a portion of the steam coal are the large lead and iron smelters of Pueblo and Denver.

The extreme southern end of the field is crossed by the main line of the Atchison, Topeka and Santa Fe Railroad, which carries the product to the markets of southern Kansas. The lines of the Denver and Rio Grande and the Colorado Southern roads from Pueblo to Trinidad are located on the plains a few miles east of the various mines, which are reached by branches from these roads; the line of the Denver and Rio Grande to Alamosa and southwestern Colorado passes westward through Walsenburg along the northern end of the field.

CANYON CITY FIELD.

This field is located in Fremont County near the town of Canyon, and is 42 miles north of the Raton field. Its western boundary is formed by the northern end of the Wet Mountain Range, from which it extends eastward to the plains; the valley of the Arkansas River marks the northern limit, and that of Newland Creek the southern. The field comprises an isolated area of 54 square miles of Laramie measures, with an average thickness of 900 feet; two-thirds of the area contain coal beds of workable thickness.

Along the western margin of the field the strata are steeply upturned against the flanks of the mountains, but rapidly flatten out, so that in the body of the field they are nearly horizontal, with a slight westward dip as the eastern edge is reached. Faulting is very rare and there are no dikes or other evidences of eruptive bodies within the area.

Extensive prospecting with the diamond drill has demonstrated the presence of as many as 16 coal beds 4 inches thick and upward, the lower beds being the most persistent and ranging from 4 to 5 feet in thickness. There are known to be two other beds which have a workable thickness at various points.

The coal produced in this field possesses excellent qualities for domestic purposes and is known throughout the plains region as the type of that class of fuel. In burning it does not coke, but produces a bright flame and leaves but a small amount of very light ash. When ground to a fine powder and ignited in a crucible it forms a slightly coherent mass. The fine coal and culm make excellent steam fuel, the demand for these sizes being fully equal to the supply from the mines. In general the coal of this field may be considered as the transition type between the lignitic coals of the South Platte field and the more highly altered coals of the Raton field.

The product of this field in 1900 was used mainly for domestic purposes, being shipped to the markets as far east as the Missouri River.

The main line of the Denver and Rio Grande Railway passes through Canyon, branches being built to the mines. The Santa Fe also has has branch lines reaching the field.

SOUTH PLATTE FIELD.

This field consists of a continuous strip of coal-bearing rocks, beginning a few miles north of Colorado Springs and extending thence nearly to the north line of the State. The western limit is defined by the upturned strata in the foothills of the Front Range, along which the field extends for a distance of 140 miles. The width of the field averages about 40 miles. The limits thus defined are those given by Mr. Hills in the articles before mentioned, and the area outlined is a conservative estimate of the extent of the Laramie formation containing coal seams of economic value. The great area east of this line in northeastern Colorado contains, with local exceptions, only coal of an inferior grade.

The productive portion of the field, which comprises about one-sixteenth of the total area, is divided into six districts. The most southern is located immediately north of Colorado Springs and includes that portion of the Palmer Lake divide which is drained by the tributaries of the Arkansas River. North of this there are no mines operated for a distance of 54 miles. The mining districts northwest of Denver, at Boulder, Marshall, Erie, Lafayette, and Louisville, form the northern group. The nonproducing eastern half of the field and a wide strip through the center have not been divided into districts, and may be considered at present as inaccessible on account of the depth of the beds from the surface, lack of railroad transportation, or the inferiority of the coal to that elsewhere produced.

The coal-bearing rocks are assigned to the Laramie, their total thickness ranging from 1,000 to 1,200 feet. The workable coal beds are included within the lower half of the measures.

The strata along the western edge of the South Platte field are steeply upturned along the base of the range, but rapidly flatten out toward the east. There are, however, gentle undulations through the body of the field, their axes extending parallel with the axis of the range. The inclination of the beds along this western border depends upon the extent to which the strata have been removed by erosion and ranges in the northern district from nearly horizontal to overturned strata, with a general easterly dip. The strata at the southern end of the field have a northward dip of about 9°. Faulting is generally confined to the northern district, in which there are numerous displacements, often of such magnitude as to prevent the extension of mine workings. The occurrence of eruptive rocks is limited to the small flow near Golden, on the western edge, and a small patch at Castle Rock, near the center of the field.

So far as known, there are from one to four coal beds in the field, from two to four being formed in the southern district and in the southern part of the northern district, and one in the rest of this district. These beds vary from 3 to 16 feet in thickness, the greatest development being in the center of the field.

The character of the coal is essentially lignitic, with local variations, though quite removed in structure from true lignite, since it mines in blocks which show the even fracture of "block" coal. It has a black color and brilliant luster. It slacks rapidly upon exposure to the air and is therefore not adapted for storage or long transportation. The best grade of fuel is produced from that portion of the field in which the strata have been subjected to movement. This is the western edge of the northern district, where the strata are steeply upturned. The poorest coal is produced in the southern district. The coal found in the upper half of the measures contains too many impurities to enter into competition with that from the lower half.

On account of the excessive moisture content of these coals their use is entirely confined to the markets in the immediate vicinity, where they have a large consumption for domestic and steam purposes, the low cost as compared with the coals of higher calorific value from the more remote fields of the State being greatly in their favor.

The proximity of the northern district to Denver, which is the most important market of the State, has induced the development of a large number of mines along the western border of this district, where the coal can be reached either from the outcrop or by short shafts. The great thickness of the overlying beds in the Denver Basin has thus far prevented the operation of any mines in the immediate vicinity of that city.

There are at present three producing mines in the southern district and eighteen in the northern, at least twelve properties in this district having been abandoned on account of increasing cost of production.

The mines of the southern district are reached by branches of the Colorado Southern and Chicago, Rock Island and Pacific railroads, those of the northern by the Colorado Southern, Union Pacific, and Burlington systems.

COMO FIELD.

Located in Park County, in the most southern of the interrange series of parks, is a strip of the Laramie strata, 21 miles long and from 3 to 5 miles wide, which comprises one of the least valuable fields of the State.

Only one-half of this area can be considered available on account of the intrusion of an eruptive mass which limits the workable area on the south. The northern end is badly faulted, which makes the cost of production excessive. The inclination of the beds along the western outcrop ranges from 30° to 50° through the workable area. The eastern border is obscured by the overlying post-Laramie beds.

The coal bed as developed in No. 5 opening contains from 5 to 8 feet of coal in the lower bench and 2 feet in the upper, separated by from 8 inches to 3 feet of shale. A mile south of this opening there is a bed containing 4½ feet of coal. Whether or not these openings are on the same bed has never been determined. The coal cakes strongly and makes an excellent locomotive fuel.

The field is nearer the Leadville and Breckinridge markets than any other in the State, and a portion of the product is used for steam purposes at these points. The greater part of the output is used by the Colorado Southern Railway, the Leadville branch of which passes through the field.

NORTH PARK FIELD.

This field comprises nearly the entire area of the most northern of the interrange parks of the State, extending from its northern end as far south as the divide separating the drainage of this park from that of Middle Park. The measures through the center of the area are covered by post-Laramie beds of considerable thickness. The beds outcropping on the northern edge of the park have a slight dip to the south for a short distance, when they gradually assume a northern dip, owing to the presence of an anticlinal fold, the beds on each side of which have an inclination of about 15°.

There are in this field apparently three workable coal beds, all remarkably free from shaly impurities and of considerable size. The largest is from 21 to 32 feet thick, another is 15 feet, and the third from 4 to 5 feet.

The character of this coal is essentially the same as that of the coals in the South Platte field, namely, lignitic, but not true lignite.

This is the least developed field in the State, the only openings being for the supply of the ranches in the immediate vicinity. The region is so remote from markets, and the probability of railroad extension into the district so slight, that there is no immediate prospect of its development.

YAMPA FIELD.

This field lies altogether on the drainage of the Yampa River. For the sake of convenience, however, a portion of the Rawlins field of Wyoming, lying within Colorado, on the drainage of the Little Snake River, is included in this description. Indeed, it is quite probable that the two fields are continuous under the great thickness of post-Laramie beds which occupy the high ground between the two exposures. This field is situated but a few miles north of the Grand River field, the two being separated by the small eroded anticlinal valley from the sides of which the strata of the two fields dip in opposite directions, doubtless at one time having been connected. There is a small area of coal-bearing measures on the top of the Flat Top Mountains, a short distance west of the main field, containing about 80 square miles of coal measures, with an average thickness of not more than 100 feet, in which four coal beds, from 4 to 5 feet in thickness, have been discovered. This area is at present practically inaccessible.

There has been very little development done in the main field—by no means enough to determine with accuracy the number of coal beds or the character of the coals, except at a few localities. There are no mines operated other than the small banks which supply the ranches. The field has no railroad connection to render the coals accessible to markets.

Both the Laramie and post-Laramie formations are coal bearing in this field, and the same uncertainty exists here as in the Grand River field in determining the exact limit between the generally shaly Montana formation below and the sandstones of the Laramie. The total thickness of the Laramie can not, however, be far from 2,000 feet.

The disturbances determining the structure of the field were those associated with the principal orographic movements and those connected with the later period of eruptive activity. The former resulted in the production of two folds, one along the southern border, extending east and west, the measures adjacent to which are inclined from 45° to 50° to the north, and the second fold on the northeastern border, parallel with the axis of the Park Range. The measures at this point dip from 10° to 15° to the southwest. The effect of the eruptions is confined to local dislocation and upturning. The area thus affected is limited, with the exception of an intrusive sheet on Elk Head Creek, to the portion along the northern border of the State.

The coal beds of the Yampa field have been exposed at a number of points along its northern border, but there has not been enough work done to determine with accuracy the number of beds contained in the field. A bed 7½ feet in thickness has been exposed on Elk Head Creek, and a few miles farther down that stream are two small beds of anthracite. This character is doubtless very local, depending upon the presence of a sneet of eruptive rock. About 8 miles southeast two beds have been exposed, one of anthracite, from 7 to 10 feet thick, and 160 feet above it a seam of semicoking coal 5 feet in thickness. The degree of alteration depends upon the nearness of an intrusive sheet, which at one point approaches the upper bed, producing anthracite, and leaving the lower bed semicoking. Along the Yampa River the coal is exposed at three places. Nearest the head of the river the exposure shows a bed 17 feet in thickness. On Oak Creek, at the eastern extremity of the fiela, there are four workable beds exposed, the lowest being 10 feet thick.

Prospecting on the Little Snake River has developed a bed 11 feet thick, above which is another, not always of workable thickness. The coal in these beds very closely resembles the celebrated Rock Spring coal, which is an excellent domestic fuel. There are several small beds higher up in the measures (one containing anthracite), none of which are of workable thickness at the points exposed.

The post-Laramie strata contain several beds of lignitic coal, which will not be developed until the coals of the underlying measures are exhausted, although at present there are several small banks operated on the beds of these measures. One bed worked near the town of Craig is 4 feet in thickness, and another, near Hayden, is a little thicker.

GRAND RIVER FIELD.

This is prospectively the most valuable field of the State, both because of its extent and because of the varied character of the coals which it contains. It forms the eastern extension of the Green River Basin, while the Wasatch field of Utah forms the western extension. It extends from the State line eastward to the base of Mount Wheatstone, near Crested Butte, a distance of over 150 miles, and from the drainage of the Yampa River on the north to the Gunnison River on the south, a distance of over 100 miles.

The meandering marginal outcrops of the coal-bearing formations are shown on the accompanying map (Pl. XXIX).

The productive area has been divided into a number of separate districts, viz: Crested Butte, Baldwin, and Ruby, in the southeastern portion; Coal Basin and Jerome Park, immediately north and separating the former from the Grand River district. These are the only portions of the field now reached by railroads, and only a small portion of the accessible areas of these districts has been developed. At the northeastern edge of the field there is a still larger area, at present nonproductive, which contains extensive reserves of coal.

The thickness of the coal-bearing Laramie varies from 2,000 feet along the southwestern border to 3,500 feet near the mines at Coal Ridge, on Grand River. The exact limiting beds are very hard to define at all points, and the change from the predominantly shaly beds of the Montana to the sandstones which comprise the greater part of the Laramie is so gradual that an arbitrary dividing line has been established at the massive sandstone immediately under the lowest of the coal beds. The determination of the summit of the Laramie is equally difficult.

As elsewhere in the Rocky Mountain region, the structure of the field has been produced by two agencies, first, the mountain-forming movement, and, second, the post-Cretaceous eruptive activity. Most of the eruptions occurred in the southern half of the field.

The number of coal beds in this field varies considerably in the different localities. In the eastern, southern, northern, and southwestern areas from two to four beds of workable size are known, while through the central tract and along the northwestern border there are from five to seven beds, containing a total of from 22 to 106 feet of clean coal.

The character of the coal invariably depends on the presence or absence of intrusive eruptive rocks and on their relation to the several coal seams. The coal along the northern border of the field is nearly all semibituminous, while that in the southern half varies from semibituminous to anthracite. The gradation is well shown on Slate River, where the mines at Crested Butte are located upon a zone of coking coal less than 1 mile wide which grades on one side into semicoking and on the other into anthracite. The coke made from the coals of the Coal Basin district is superior to any other produced in the Rocky Mountain region, being remarkably similar to the Connellsville (Pa.) product, both in chemical composition and in physical structure.

The various parts of this field which are at present productive are reached by branches of the Denver and Rio Grande and Colorado Southern railroads. These roads carry the product to the markets of the eastern portion of the State or deliver it to the other roads that convey it to the markets as far west as San Francisco.

LA PLATA FIELD.

This, the southernmost of the fields on the western slope of the Rocky Mountains, is located in the southwestern part of the State and extends thence into New Mexico and Utah. Hence the State lines form portions of both the southern and western boundaries of the Colorado field. The other boundaries are well defined, topographically, by a line of high bluffs resulting from the erosion of the underlying soft marine beds.

The extent of the field along the southern State line is 85 miles, north of which it extends about 15 miles, giving a superficial area of 1,250 square miles in which the coal-bearing strata are either exposed and accessible or covered by later deposits. The drainage channels, consisting of the San Juan, Piedra, Los Pinos, Florida, Animas, La Plata, and Mancos rivers, have cut deep canyons across the field and deeply notched the northern margin.

There are two productive districts, the Durango and the La Plata. The first is located near the town of that name, and its product is entirely coking coal. The La Plata adjoins it on the west. There are several nonproducing districts which will doubtless be developed as this part of the State becomes more thickly settled.

There are in this basin two distinct coal-bearing horizons, both of which are probably in rocks of Montana age. In the upper series massive, light-colored sandstones predominate, while the lower series consists of thin-bedded sandstones with numerous bands of shale.

The inclination of the strata along the northern border of the basin varies from nearly horizontal at each end to 36° on the Animas River near the center of the northern margin. This high angle is confined to the upper series. The lower has not been affected to so great an extent by the flexure caused by the upheaval of the La Plata Mountains, which are adjacent to this part of the field on the north. There are no bodies of eruptive rocks of any magnitude within the area, though the great La Plata Mountain eruption doubtless had a decided effect upon the character of the coal along the northern border.

The upper series contains a great aggregate thickness of coal at all points along its outcrop. The individual seams, however, vary to a marked extent. At one point in the Durango district there is a total of 80 feet of coal in 100 feet of strata. This marks the thinnest point of the intervening beds of clay and shale which a few miles to the east have separated the coal into four distinct beds. The lowest is 4 feet thick and is separated by 100 feet of barren strata from a bed 15 feet thick; this in turn is separated by 50 feet from a bed 20 feet thick, which is 80 feet from the top seam, containing 5 feet of coal. The seams of the lower series are generally small, the thickest reaching a total of but 5 feet of coal.

The coal at the two extremities of the field is of the semicoking or domestic variety, while that of the central portion of the northern border possesses pronounced coking qualities. A few bee-hive ovens are in operation near Durango, the coal used being obtained from the lower measures, since none of that from the upper measures produces a coke. The southern and central portions of this field have not been examined sufficiently to give any detailed idea as to the character of the individual seams or of the structural features of that portion of the area.

The market for the product from this field is very limited, being confined almost entirely to the mining towns of the La Plata Mountains and the smelter at Durango.

The Denver and Rio Grande and the Rio Grande Southern roads are as yet the only railroads constructed to this part of the State, though as all of the canyons form practicable railway routes it is thought that one or more of the trunk lines are contemplating westward extension by the way of Durango.

TONGUE MESA FIELD.

This includes a long, narrow, isolated strip of Laramie measures occupying the ridge between the Cimarron and Uncompahgre rivers. The strata, which are not steeply inclined, contain two beds of workable thickness. The lower is from 15 to 20 feet thick, the upper, 400 feet above, is 5 feet thick and contains a better grade of coal. The coal is dry, closely resembling the lignitic coals of the eastern slope. As there is no railroad connection the production is limited entirely to the supply of local demands. The greater part of the output is consumed in the town of Montrose, on the line of the Denver and Rio Grande Railroad, about 10 miles northeast of the field.

COAL IN THE DAKOTA FORMATION.

At a number of places through the western part of the State, south of the Grand River drainage, coal beds are exposed at the base of the Dakota formation.

As a rule these seams are so thin and the coal is of such inferior quality that they are not of economic value. There are, however, places at which they attain a thickness of 20 inches to 3 feet, and owing to the distance from the railroads these areas are of value for local supply, and several small mines are in operation. The character of the coal depends entirely upon the proximity of some body of eruptive rock, the alteration at two points having produced anthracite. The beds at these points are so badly faulted, however, as to render the coal of no value. The utilization, in a large way, of the coals from these areas will not take place until the coals of the other fields of the State are nearly exhausted.

WYOMING.

Coal-bearing rocks underlie a larger proportion of this State than of any other Rocky Mountain State. Most of this area, however, is included within the plains region, while the fields of Colorado are adjacent to the main mountain ranges. The same is to a large extent true of the fields of Montana. Hence, with a few exceptions, the coals of the various fields of this State are of a lower grade than those of Colorado and Montana. There is no field in the State where mining operations are now conducted in which the coal will produce a good grade of coke, nor has any marketable anthracite been discovered within its limits. There are extensive areas through the northern and eastern portions of the State underlain by the Laramie formation, which contains beds of lignitic coal, and a large area in the south-western portion containing coal of higher grade.

The product from the mines of the State finds a ready market along the line of the Union Pacific Railroad and its immediate connections from the Missouri River westward to San Francisco and Portland.

BLACK HILLS FIELD.

This area extends beyond the boundary line between Wyoming and South Dakota, but no coal beds of workable thickness have as yet been discovered in the latter State.

The coal horizon is in the lowest of the Cretaceous formations recognized in this section. The coal-bearing rocks appear to have been deposited in basins eroded in the underlying Jurassic. The workable bed in the Newcastle district is only about 50 feet above the bottom of the Dakota, and the areas containing the workable beds are entirely separate. Up to the present time but two such basins have been discovered, both of them being in Wyoming. These are the Hay Creek district, located at the extreme northern end of the field, and the Newcastle district, near the center of the western margin.

The strata in the Newcastle district are free from faults, and dip about 8° to the west. In the Hay Creek district they dip 8° toward north, and, with the exception of a large fault along the eastern edge of the district, having a vertical displacement of about 200 feet, there are no evidences of serious disturbances.

There appears to be but one coal bed of workable thickness in each of these basins. In the Newcastle district it has a thickness in some places of 9 feet, the average thickness being about 5½ feet. In the Hay Creek district the coal is 4½ feet thick.

The product from both of these districts has a peculiar structure, being dense and heavy, and in mining it breaks into shaly fragments. There are also seams of impure coal with dull luster throughout the bed. The coal from these does not coke, while that from the other portions of the bed makes an inferior grade of coke in the ordinary beehive oven.

The Newcastle district is on the line of the "Burlington Route" to the Northwest. Most of the product from the two mines is used as a locomotive fuel by that line, while a small portion is converted into coke for use in the smelter at Deadwood, 170 miles from the mines. The Hay Creek mines are reached by the Wyoming and Missouri River Railroad, nearly all of the product being used by that road.

The output from this field in 1900 was 530,924 tons, of which 388,110 tons were used by the railroads and 32,460 tons were converted into coke. The remainder was sold in the markets of eastern Wyoming, western South Dakota, and Nebraska.

CARBON FIELD.

This field is located immediately southeast of the Hanna field, the mines at Hanna and Carbon being but 6 miles apart. It is the first of a series of fields crossed by the Union Pacific Railway. The field extends about 12 miles north and south, the southern end terminating at the valley of the Medicine Bow River. At this end the outcrops of the lowest bed are 6 miles apart, and gradually approach toward the north. The strata at the northern end of the field are badly faulted, owing to the proximity of the mountain ranges. At the southern end they are more regular, the dip being a few degrees to the north. This northward dip is due to the uplift of the Medicine Bow Range immediately south of the field.

At the northern end of the basin only one coal bed is exposed, having a thickness of 7 feet in the mines at Carbon. South of this, other beds in the lower part of the measures are exposed, while the upper bed has been carried away. There are two beds in the lower measures, which are separated at the southern extremity by 150 feet of sandstones and shale. The lower one has a thickness of 7½ feet and the upper of 23 feet.

All of the coal is semicoking and excellently adapted for locomotive use. The entire output of the mines at Carbon is used for this purpose by the Union Pacific Railway. The amount mined in 1900 was 174,492 tons.

HANNA FIELD.

This field is located in Carbon County and is connected at the northern extremity with the Rawlins field. From this point it extends southeastward a distance of 65 miles, the eastern end being at the Hanna mines on the line of the Union Pacific Railway. The northern boundary is formed by the granite uplifts of the Ferris and Seminole mountains, south of which the productive area extends from 6 to 12 miles.

Both the Laramie and Fort Union formations contain coal beds of workable thickness. The strata of the lower formation are steeply upturned along the base of the mountains and are intersected by a series of parallel faults which would seriously interfere with mining operations. The southern end of the field is comparatively free from such disturbances, and it is here that all of the mining operations are conducted.

The upper measures contain but one coal bed of workable thickness. This was opened at the Dana mines, but the coal was of such inferior grade that these mines have been abandoned. In the lower measures there are three beds at present worked. The upper bed is from 20 to 25 feet in thickness. About 350 feet below it is the middle bed, from 6 to 8 feet thick, and 300 feet lower is the bottom bed, 20 feet thick.

There are still other beds lower in the measures that have not developed a workable thickness. The coal of these measures is semibituminous and well suited for both locomotive and domestic purposes.

The amount of coal mined in the Hanna field in 1900 was 355,167 tons, the product being used for domestic and steam purposes along the line of the Union Pacific as far east as the Missouri River.

RAWLINS FIELD.

This field consists of a narrow strip of the coal-bearing rocks, about 65 miles in length, extending both north and south of the Union Pacific Railway. The eastern edge of the field is a few miles west of the town of Rawlins. There are no extensive mines operated within the limits of the field, and but little prospecting has been done. At present, however, there are several parties making a thorough investigation of the field with the probable intention of opening mines.

This field marks the eastern limit of the southern Wyoming basin, the coal-bearing formations being exposed along the western edge of the Rawlins uplift. The coal beds of workable thickness in this field are contained in the Laramie formation, although the overlying Fort Union formation is productive at other points in this basin. The northern end of the Rawlins field is terminated by the granite of the Sweetwater Hills. The Laramie beds at this end of the field have a southwesterly dip gradually changing to the west, which is the general direction of the dip as far south as the Elk Mountains in Colorado. The dip, with local exceptions, is generally slight. There are no serious displacements within the area, nor are there any large eruptive bodies that would tend to alter the character of the coals.

There are four coal beds exposed at the northern end of the Rawlins field along the base of the mountains. They vary in thickness from 5 to 10 feet, but so little prospecting has been done that it is impossible to give any information as to the continuity of the several beds. There are two beds opened near the line of the railroad, and at the southern end of the field there is a seam about 10 feet in thickness which is quite persistent, with another immediately above not always workable.

The character of the coal at the northern end of the field is lignitic, but that at the southern end is a much higher grade, being very similar to the Rock Springs coal in composition and general appearance. The small amount of coal mined near the line of the railroad is of an intermediate grade.

The coals of this field along the line of the railroad have not been developed to any great extent owing to the superiority for domestic use of that mined at Rock Springs, and of the Carbon product for use in locomotives. The only market for this coal is the town of Rawlins.

ROCK SPRINGS FIELD.

This field is located in the central part of Sweetwater County, on the main line of the Union Pacific Railway. It contains three productive districts, namely, Rock Springs, Point of Rocks, and Black Butte. There is a large area, as yet undeveloped, extending a distance of about 30 miles north and south of the railroad.

The field forms an elliptical area extending from Leucite Buttes southward a distance of 60 miles. Its greatest width is about 45 miles on the line of the Union Pacific Railway.

The coal-bearing formations of the southern Wyoming basin extend from the Fremont County line on the north into Colorado, and from Carbon County on the east as far as Hams Fork on the west. The Laramie and Fort Union beds have a uniform dip of from 4° to 15° in all directions from a center formed by the Bitter Creek uplift. The Rock Springs district is located on the western dip, while the Point of Rocks and Black Butte districts are on the eastern side. Both the Laramie and Fort Union formations contain coal beds of workable thickness. The strata surrounding this uplift are free from rolls, and only two faults of any size have been discovered, both in the southern portion of the field. The northern and southern extremities of the field have not been thoroughly explored, but the indications are that the same series of coal beds occur there as at Rock Springs, though perhaps not of as great thickness.

The following general section of the coal-bearing strata has been developed in the Rock Springs district:

Section of coal-bearing strata in Rock Springs district.

	Feet.
Top, coal bed VI.	
Rock	850
Coal bed V.	
Rock	150
Coal bed III.	
Rock	175
Coal bed I.	
Rock	180
Coal bed VII.	
Rock	160
Coal bed H.	
Rock	80
Coal bed VD.	

The following sections indicate the character of the various beds:

Section of coal bed VI:

	Ft.	in.
Shale	1	6
Coal	1	2
Bone	0	6
Coal	2	1

Section of coal bed VI—Continued.

	Ft.	in.
Shale .... 6 in. to	1	0
Coal	1	6
Bony coal	0	5
Coal	1	11
Section of coal bed V:		
Coal	0	6
Shale	0	1
Coal	1	4
Shale	0	3
Coal	1	2
Shale	0	1
Coal	0	9
Shale	0	1
Coal	2	2
Section of coal bed III:		
Coal	1	10
Bone	0	7
Coal	1	8
Section of coal bed I:		
Coal .... 9 to	11	0
Shale, about in the center of the bed	0	11
Section of coal bed VII:		
Coal .... 4 ft. 8 in. to	7	0
Shale, in the center of the bed	1	5
Section of coal bed H:		
Coal .... 2 to	2	9
Section of Van Dyke coal bed:		
Coal	0	6
Sandstone .... 1 in. to	0	5
Coal .... 3 ft. 6 in. to	3	10

Bed III in other parts of the district varies from 4 feet 8 inches to 7 feet 8 inches of coal.

The section at Point of Rocks shows the same number of coal beds, though of less thickness and slightly inferior quality. The section at Black Butte—Fort Union—contains but one bed of workable thickness. It is 11 feet thick, separated into two benches by 14 inches of shale about the middle of the bed.

The coals of the Laramie are semibituminous and are noted throughout the West as the best coal mined for domestic purposes. The coal of the Fort Union is lignitic.

HAMS FORK FIELD.

This field is located in the southwestern part of the State, its northern end being about 10 miles north of the mines at Diamondville. It occupies a narrow synclinal trough about 60 miles in length, and toward its southern end is separated into several small areas by the overlying Tertiary beds. The field is about 10 miles wide at the northern end, gradually decreasing toward the south owing to the encroachment of the overlying Tertiary.

There are two recognized productive horizons separated by about 5,000 feet of nonproductive strata. The lowest beds have been assigned to the lower portion of the Cretaceous, probably between the Dakota and Benton formations. These constitute the Bear River formation. The upper coal beds are in the Laramie formation.

The strata of this field contain numerous parallel flexures with north-south axes.

The strata along the eastern edge dip 26° toward the west, while those of the upper series along the western border have a like inclination to the east. The beds of the lower measures are obscured on this side of the field by the Tertiary formations.

The only extensive development of this field has been along the eastern margin near the northern end. The lower series here contains five coal beds of workable thickness, two of which are mined. The upper bed varies from 6 to 18 feet in thickness and the lower from 4 to 6 feet. The beds of the upper series attain a much greater thickness, there being at least five between 4 and 22 feet thick and one which shows at Adaville a thickness of 86 feet.

The coal of the lower series is semibituminous, is very bright in appearance, and contains a small amount of ash. That of the upper series is all lignitic.

There are at present four operating mines in this field, all of which are confined to the beds of the lower series. Two of these are at Diamondville and two at Kemmerer.

This field is crossed by the Oregon Short Line, and a large portion of its product is used by this road. The mines at Diamondville are owned by the Amalgamated Copper Company, and the product is used at the mines and smelters of that company in Butte and Anaconda.

ALMY FIELD.

This field lies 7 miles west of the southern end of the Hams Fork field, the intervening area being covered by Tertiary beds. The outcrop of the coal-bearing rocks forms an area 12 miles in length, north and south, by 6 miles in width.

There is one seam worked, which has an average thickness of 22 feet of clean coal, which is a high-grade lignitic. It contains a much lower percentage of moisture than the same class of coals of the plains region. There are two operating mines in this area, both of which are located at Almy. These mines are on the main line of the Union Pacific Railway.

The other areas separated from the southern end of the Hams Fork field do not contain any producing mines.

HENRYS FORK FIELD.

This includes a small area of Laramie strata extending along the Wyoming-Utah boundary, 35 miles south of the Rock Springs field.

The area is divided into two districts by the valley of Green River, the largest being on the east of the river. The distance from lines of transportation has limited exploration in this field, and only one coal bed of workable thickness has been discovered. The area contains about 150 square miles of coal-bearing rocks.

TETON FIELD.

This is an unexplored area of coal-bearing rocks located near the head of Wind River between the Wind River and Shoshone ranges. The area is so surrounded by the mountains as to be practically inaccessible, and has therefore received very little attention.

SUBLETTE FIELD.

The southern end of this field is about 12 miles west of the Hams Fork field, the two being separated by an area of great disturbance, in which formations as low as the Devonian are exposed.

The field extends northwestward along the southern end of the Sublette Range into Idaho, occupying a narrow trough. The strata are very badly broken and have a steep dip along each side of the trough toward the center. Only a single mine has been opened in this field. It was located at Cokeville, near the Idaho line, and has recently been abandoned, owing to the excessive cost of mining the coal. The coal is semicoking, but does not make a strong coke in the ordinary beehive ovens.

BIGHORN BASIN FIELD.

This field is located in the northern portion of the State, and is probably the southern extension of the Clarks Fork field of Montana. It extends from the State line southward 95 miles to the Owl Creek Mountains, and is limited on the east and west by the Bighorn and Absaroka ranges. This field consists of a synclinal basin, the eastern and western edges of which are marked by the mountain ranges mentioned. There can be no question that the entire basin is underlain by the coal beds, though they are so deeply covered by the overlying rocks as to be inaccessible in the center of the basin, and it is only along the upturned edges that the coal can be reached.

There has been but little development of the coal in the past, owing to the lack of transportation facilities, but the recent extension of the "Burlington" to this part of the State is causing considerable activity in the coal development.

Both the Laramie and the post-Laramie formations, the latter probably Fort Union, contain valuable coal beds.

The upper measures are composed of alter. ating bands of shale, soft sandstones, and clays, with an occasional bed of harder sandstone. The soft beds have been deeply eroded, leaving the surface exceedingly rough and uneven. The lower measures are composed of harder material, the sandstones at the base being quite massive. Owing to the small amount of development, but little information is to be obtained as to the individual coal beds. In the upper measures near the State line and on the eastern edge of the field two coal beds have been discovered. The lower is 4 feet thick, and 150 feet above it is the main bed, which has a thickness of about 6 feet in the northern end of the basin. The coal in both of these beds is lignitic, resembling the better grades of this class of coal mined in Colorado. Farther south there has been more demand for coal by the large ranches in the center of the basin, and there has, therefore, been more exploration. There is an opening on a seam in the upper formation near the center of the area, where 6 feet of very fair lignitic coal is found. At the southern end of the field there are several prospects, some of which are at present being developed on an extensive scale. Near the town of Meeteetse the lower formation is exposed, disclosing two coal beds, the lower 6 feet in thickness and the upper about 4 feet. Farther south and east are other prospects in which the lower is 4 feet thick and the upper but 3 feet. The coal here has a peculiar appearance, being brown and lusterless, and in mining it comes out in very fine pieces and dust.

WIND RIVER FIELD.

This field is located in the central part of the State, in Fremont County. Since it is fully 90 miles from the nearest railroad, but little development has been done, the only demand for fuel being in the town of Lander and the ranches in that vicinity.

The Wind River uplift has here exposed the Laramie strata beneath a great thickness of the overlying Eocene. The exposures extend around the southern end of the Wind River Mountains in a narrow strip about 30 miles in length. There is a second small exposure of the same formation a short distance east of the main body, along the northern end of the Rattlesnake Hills, the connecting beds being covered by the Tertiary.

The strata are steeply inclined along the northern edge of the Wind River Mountains and the Rattlesnake Hills, but flatten out rapidly to the north and are covered by the Tertiary beds. The structural features have not been worked out in detail, but there is no evidence of extensive displacement. The few faults observed are parallel with the axis of the uplifts.

There are two coal beds exposed along the base of the mountains, one 7 feet, the other about 4 feet in thickness. The character of the coal is similar to that of the Rock Springs field—semibituminous.

There is a small area of the Dakota formation west of the town of Lander, containing coal beds which, however, are not of workable thickness.

CASPER FIELD.

This area is but a few miles in width, north and south, and extends eastward from the base of the Rattlesnake Hills a distance of 30 miles, around the northern end of the Laramie Mountains.

The strata belong to the Laramie formation, and the coal is all lignitic. There is a small mine 6 miles southeast of Casper which supplies the fuel for that point. Aside from this mine no prospecting has been done to determine the value of the area.

POWDER RIVER FIELD.

This field comprises a large district east of the Bighorn Range, its total area being about 8,950 square miles. Notwithstanding its great extent, this is the least important of the large fields of the State, owing to the character of its coal.

The strata along the base of the Bighorn Mountains have a slight eastward dip, but rapidly flatten out and continue nearly horizontal to the eastern border of the field, where they have a slight westward dip due to the Black Hills uplift.

The coal-bearing strata throughout this field consist of soft sandstones and clays, with occasional beds of harder sandstone. The streams have cut deep channels through the beds, exposing the coal beds, and in many places these have been consumed by fire.

All of the coal of this field is lignitic, and owing to its high moisture content it makes a fuel of low efficiency. By reason of the rapid disintegration of the coal on exposure to the air, the chief value of the field lies in the limitless supply of fuel which it affords for the settlers of this treeless plains region.

The beds vary from 6 to 20 feet in thickness and are generally rather free from impurities.

There are 4 shipping mines in the field, 2 of which are located at Sheridan, in the northeastern portion, on the line of the Burlington and Missouri River Railroad. A small portion of the product is used as a locomotive fuel by that road, specially designed fire boxes and grates being employed. The other mines are located at the southern end of the field, on the line of the Fremont, Elkhorn, and Missouri Valley Railroad. Most of the output of the mines is consumed in their immediate vicinity. There are mines near the towns of Buffalo and Douglas which supply the local demand, besides numerous small "banks" which supply the ranches in the various parts of the field.

NEW MEXICO.

The largest fields are located in the northern part of the Territory, and only those portions adjacent to railroads have been thoroughly explored. Through the center of the Territory there are a number of small, isolated tracts, some of which have been developed and contain producing mines. So far the only horizon that has developed coal beds of value is the Laramie, although it is by no means certain that some of the other formations may not also contain valuable deposits.

The great value of these fields lies in their proximity to an extensive region in Arizona, Texas, southern California, and the Republic of Mexico, in which very little coal of value has been discovered.

RATON FIELD.

This is the southern end of the Raton field of Colorado, and extends from the State line south to the Cimarron River, a distance of 40 miles. The western border is at the base of the main Rocky Mountain Range, from which it extends 50 miles to the east. The field has not been sufficiently explored to correlate the various coal beds with those found in Colorado. The strata at the southern border are badly broken, owing to the eruptive activity which has centered in the Raton Mountains. There are frequent rolls, which tend to reduce the thickness of the coal in places below the limit of profitable mining. The thickness in the producing districts varies from 3 to 6 feet.

The entire product from the operating mines makes a good grade of coke. Ovens are in operation at Gardiner, the plant being operated by the Maxwell Land Grant Company.

The main line of the Santa Fe crosses the field near its center, the Raton Pass being located within the limits of the field.

LA PLATA FIELD.

The San Juan Basin extends south of the Colorado line into the northwest corner of the Territory. Also the southern extension of the eastern limb of the La Plata field of Colorado is found in the western part of Rio Arriba County, N. Mex.; but these areas have not been thoroughly explored. Their general features, however, are the same as those of the main body of the field in Colorado. The strata along the eastern border of the field have a uniform dip toward the west and are exposed only within a narrow belt, passing under the Eocene beds that cover the entire central portion of the basin.

No mining operations of any magnitude are conducted in the New Mexico portion of this field, the entire product being used in the immediate vicinity of the mines.

MOUNT TAYLOR FIELD.

This forms the southeastern exposure of the coal-bearing formations of the San Juan Basin. The center of the southern boundary of the field is located 13 miles northeast of Grant station on the Santa Fe Railroad and immediately north of the Mount Taylor uplift. The strata at this point are exposed in a much broader belt, owing to the greater elevation of the southern edge by this uplift.

The coal beds form a portion of the upper horizon described in connection with the measures of the La Plata field of Colorado. The lower Montana measures thin out rapidly toward the south and do not contain beds of workable thickness at any point along the southern edge of the basin. The average dip is but 4° to the northwest and the strata are very uniform, no evidences of serious disturbance being noticeable. There are two coal beds in the lower portion of the measures, the lower 6 feet in thickness, the other, 150 feet above it, 4½ feet thick.

The coal is a high-grade lignitic type, similar to that mined in the Gallup field, 60 miles to the west.

There are no operating mines in the field, as there are nc railroad facilities.

GALLUP FIELD.

This field extends north and south of the Santa Fe road and forms the southern end of the San Juan Basin. The overlying Eocene beds divide the northern end of the field into two arms, one forming the southeastern and the other the southwestern edge of this basin. The main body of the field extends southward from the junction of these two arms a distance of 75 miles, the width gradually decreasing toward the southern end.

As mentioned in connection with the Mount Taylor field, the lower measures, which produce the higher grades of coal in the La Plata field of Colorado, thin out rapidly toward the south, and they are not represented at all in the Gallup field. The productive strata at this point are the same as the upper series farther north, and throughout this field have an aggregate thickness of 1,200 feet. The coal seams occupy two distinct horizons, separated by 400 feet of barren rock.

The only portion of the field which has been thoroughly explored is that immediately adjacent to the line of the railroad at Gallup and northward to the mines at Clarkville. Throughout this area the measures have a uniform dip of 8° to the southwest, and with the exception of a fault extending parallel with the eastern outcrop they are generally regular.

Each of the coal-bearing horizons contains five seams, varying from 4 to 6 feet in thickness where mined, though not all are of a workable thickness throughout the entire field. In the producing area immediately adjacent to the town of Gallup some of the seams of the upper horizon have been entirely removed by erosion.

The product is all of one grade, semibituminous, resembling the coal from the Rock Springs district of Wyoming.

The output from this field finds a ready market for domestic and manufacturing purposes as far west as Los Angeles.

Nearly the entire product of the mines at Clarkville is used in the mines and smelters at Jerome, Ariz., the ownership of the famous United Verde copper mines and these coal mines being the same.

LOS CERRILLOS FIELD.

This field is located in the central portion of Santa Fe County, its northernmost point being 3 miles from the main line of the Atchison, Topeka and Santa Fe Railway, and 20 miles south of the city of Santa Fe. The field consists of an isolated area of the Laramie formation, about 1,000 feet in thickness, covering 35 square miles, and disappearing under the Tertiary beds to the east.

The only disturbance that has seriously affected the strata occurred in connection with the period of eruptive activity, the results being more noticeable in the alteration of the coals than the dislocation of the strata. The measures have an average inclination of 18° to the east.

There are three coal beds in this field, varying in thickness from 2½ to 7 feet, the beds at the northern edge being thinner than those farther south, but of greater economic value, owing to the better grade of the coal.

At the northern end of the field an intrusive sheet of diorite has penetrated the strata in close proximity to the coal beds. This has resulted in the alteration of the coal to an anthracite of good grade. The coal toward the south passes into coking and semicoking varieties, the transition being very gradual.

The anthracite mined in the northern portion of the area finds a ready market for domestic purposes from Denver to San Francisco. The production of anthracite in this field for 1900 was 36,216 tons. The semibituminous product goes to the markets of New Mexico, Arizona, and Texas.

TEJON AREA.

This area is located a few miles southwest of the Los Cerrillos field and may represent a continuation of the same coal horizon in this direction. The area covered is about 35 square miles. The strata have a uniform dip of 20° to the east and disappear under the Tertiary beds.

There is but one coal bed of workable thickness exposed, varying from 4 to 5½ feet. The coal is very clean and is semibituminous in character.

There are no mines in operation in the area.

JARILLOSA FIELD.

This consists of a small area of the Laramie formation situated 25 miles west of the main line of the Santa Fe Railroad, on the line between Socorro and Valencia counties.

The field extends about 10 miles north and south, and along its eastern margin the coal-bearing strata pass under a large eruptive mass. The average dip is 10° to the east. The productive area is materially reduced by the badly broken condition of the strata throughout a large part of the field.

There are three beds of coal, only one of which attains a workable thickness, of 28 to 30 inches. The coal is, however, so remarkably clean and produces such excellent coke that this thickness is within the limit of profitable mining.

There are no mines operated in this field, owing to its distance from the railroad.

CARTHAGE AREAS.

These consist of a number of isolated patches of Laramie measures, having an area of about 60 square miles, situated 8 miles east of the town of San Antonio, on the line of the Santa Fe Railroad. The workable area is very limited, owing to the thinning out of the coal beds and to extensive faults which traverse the measures. The dip varies from 15° to 28° to the east.

There are several coal beds in the lower part of the measures, but only the lowest is of a workable thickness, varying from 4 to 10 feet.

The product makes a fair quality of coke; but owing to the excessive amount of faulting, the area has littie value. There is a small amount of coal at present mined, all of which is hauled by wagons to the main line of the railroad.

WHITE OAKS FIELD.

This field is situated in Lincoln County, at the end of the El Paso and Northeastern Railway. The coal-bearing strata have been eroded in such a manner as to leave six separate areas. The field extends 40 miles north from the town of Three Rivers and has a width of about 20 miles. The eruptive mass of the Carrizo and Nogal mountains occupies the center of the field.

The two southern districts are near the town of Three Rivers and have received but little attention. The western district, around the base of the Carrizo Mountains, includes the mines at White Oaks. The Salado district is the easternmost and is the only one which has been thoroughly explored.

Both the Laramie and Fox Hills formations contain coal beds. Those of the lower formation, however, are not of workable thickness at any of the points where prospecting has been done, with the exception of one place in the White Oaks district, where the seam attains a thickness of 3 feet. In the White Oaks district there are five beds, ranging from 4 to 5½ feet in thickness.

The character of the coal in various parts of the field depends entirely upon its proximity to some body of eruptive rock. Hence the coal ranges from semicoking and coking to anthracite.

There are several recently opened mines in the White Oaks district.

The principal market is El Paso, Tex., 135 miles south of the mines, and the several railroads diverging from that point. A portion of the product reaches the markets along the lines of the Southern Pacific and Atchison, Topeka and Santa Fe railroads in southern New Mexico and Arizona, and a small amount is exported to the Republic of Mexico.

MORA COUNTY AREA.

This is a small area of the Laramie, located in the extreme northwestern part of Mora County; since it is separated from all possible markets by a considerable extent of desert, it can have no possible value for a number of years.

GILA RIVER AREA.

There is a small area of coal-bearing rocks immediately east of the Gila River in the northern part of Grant County, from which coal was mined in the early days to supply the mining camps around Silver City.

The limits of this area have not been determined, but it is without doubt of very small extent. The coal bed, where mined in the early days, was about 16 inches in thickness.

UTAH.

The areas of the coal-bearing rocks in this State have received less attention than those in most of the other States of the Rocky Mountain region. Such exploration as has been done has been limited almost entirely to the areas along the existing lines of transportation, and only at isolated localities even in those areas. Hence it is impossible to estimate the probably productive area of the State with any degree of accuracy.

The horizons at which seams of workable thickness have been discovered occur in several of the Cretaceous formations as well as in a small area of the Wasatch Eocene. The better grades of fuel are found in the Laramie formation, although there are areas within the State in which the Bear River, Montana, and Colorado formations contain coal beds of workable thickness.

The character of the coal from the producing mines is nearly all semibituminous, none of the small areas of lignite being worked.

There is a small quantity of coke produced, but its structure is not equal to that of coke produced in the Colorado fields on the western slope of the Rocky mountains.

Most of the markets reached by the Utah coals are within the limits of the State, namely, Salt Lake, Ogden, Provo, Park City, and the various mining towns. A small portion of the coal from the Pleasant Valley mines is shipped to the San Francisco market, where it compares very favorably with the coals from Washington and British Columbia.

WASATCH FIELD.

The outcropping southern edge of this field extends eastward from the Wasatch Mountains to the Colorado line. The field forms the western end of the Green River Basin, of which the Grand River field of Colorado forms the eastern end.

The western portion of the field extends along the base of the Wasatch Mountains for a distance of 60 miles. The outcrop then turns southeast, following along the edge of the monoclinal ridge of the Roan or Book Cliffs, a distance of 140 miles, to the Colorado line. This line of steep cliffs marks the southern margin of the field, from which the coal-bearing rocks extend northward to the Uinta Mountains. Nearly the whole of this basin is covered by the Eocene beds, the Coal Measures being exposed in a narrow strip along its southern and western borders and at a few points along the northern edge where erosion has carried away the overlying formations. The area covered by solid color on the accompanying map (Pl. XXIX) is intended to indicate that portion of the field in which the coal-bearing rocks are exposed.

There are three producing districts in this field, namely, Sunnyside, situated near the center of the southern margin, Castle Gate, at the point where the outcrop swings to the east; and Pleasant Valley, at its southwestern extremity. The small area on Ashley Creek, on the northern border, is so remote that it can not be considered as a productive district, the small amount of coal mined being for local use.

The Laramie measures throughout this field are about 1,200 feet thick, and the coal beds thus far discovered are near the base of that formation.

The measures adjacent to the mountains on the west have been subjected to serious displacement, while those along the eastward extension generally have a uniform northward dip of 10° to 15°. There is a series of rolls in the strata east of the most easterly producing district, caused by intrusions in the strata south of this field.

Only a single coal bed is worked in each of the districts, and not enough prospecting has been done to determine whether or not it is the same bed in all the mines. The workings in the western districts have developed from 4 to 8 feet of coal, while in the Sunnyside district, 80 miles to the east, there is a thickness of 12 feet.

The product from the Pleasant Valley and Sunnyside districts is semibituminous, that from Pleasant Valley being the better grade. The product from the Castle Gate district is a coking coal, although the coke produced in the ordinary beehive ovens is not one of the best as to structure, being too reedy.

A large proportion of the product from the mines of these districts is used by the railroad companies for locomotive fuel. A part of that from the Pleasant Valley district reaches the markets as far west as San Francisco, the rest being used to supply the home markets.

ASHLEY CREEK AREA.

There is a small exposure of the Laramie of undetermined extent along the northern border of the basin, the coal outcropping along the west side of Ashley Creek. The bed opened ranges from 3 to 6 feet in thickness and contains a fair grade of semibituminous coal.

Owing to the distance from the railroads, the only value of this area at present lies in the supply of fuel for the settlers in the vicinity.

COALVILLE FIELD.

This field is located near the southwest corner of Wyoming, 50 miles northeast from Salt Lake. It consists of a narrow area of the coal-bearing rocks of the Bear River formation, extending northeast and southwest along the base of one of the eastern spurs of the Wasatch Mountains. The beds have an inclination of about 19° to the northwest, the portion adjacent to the mountains being badly broken. The movement causing these fractures has rendered the coal very friable, a large amount of fine coal being produced in mining. There are two beds of workable thickness in the measures—one 4 feet, the other from 8 to 12 feet thick. The coal is semibituminous, but of an inferior grade. The principal market is the mining camp, Park City, since the product can not compete with the fuels from the Pleasant Valley district in the Salt Lake market. There are five producing mines in the field.

PROVO CANYON AREA.

A small area of coal-bearing rocks of undetermined age outcrops in Provo Canyon a short distance from the town of Provo. Considerable development work has been done at various times, but nothing of economic value has as yet been discovered.

SOUTHERN UTAH FIELD.

This field is located in the southwestern part of the State and has received but little attention, having been until very recently remote from all railroads. The western end of the field is now only 45 miles from the line of the Utah and Pacific Railroad, and with the settlement of the country along that line this field will doubtless be further developed.

The field extends from the hills back of Cedar City southeastward around the Kolob Plateau nearly to the Colorado River, a distance of 150 miles. The coal beds occupy the lowest part of the Colorado formation, the greatest exposure being around the eastern end. To the east the coal outcrops along the margin of the plateau, and is almost inaccessible from the valley. The general dip is toward the northeast. The beds at the western end are cut off on the north by a fault which will render mining operations in that direction impossible. There are also several large eruptive bodies in that portion of the field, the overflows from which have obscured the outcrop in a number of places.

At the western end of the field there are two coal beds of workable thickness separated by 500 feet of beds which contain several small coal seams. The lower one is 8 feet thick and the upper from 4½ to 6 feet. Both of these beds gradually thicken toward the east.

The coal at the western end of the field is semibituminous, but soon changes toward the east to lignitic. There is a small amount of coal mined for use at Cedar City and in the surrounding country.

HENRY MOUNTAIN FIELD.

This is a small field in the southern part of the State, which has received but little attention owing to its isolated situation.

The coal-bearing rocks form a fringe around the base of the Henry Mountains, the exposed area amounting to only about 600 square miles. There is but one seam, located at the base of the Blue Gate sandstone (Laramie), which contains 4 feet of clean coal of a semibituminous character. A small amount of the coal is mined for the use of the mining camps along the Colorado River.

NORTH DAKOTA.

All of the coal of this State is lignitic in character and disintegrates so rapidly upon exposure that it must be used within a short time after leaving the mine. Hence it can be used only for domestic fuel and under stationary boilers. The great value of these lignite beds at the present time is in the unlimited supply of fuel for the settlers of this treeless plains region. Very little labor is necessary to procure the coal. At many points it is merely necessary to scrape off the surface and quarry the coal. Numerous attempts have been made to produce a satisfactory briquet of this coal, but up to the present time none of them have been successful, owing to the high cost of the material used for a binder. Without doubt, however, some method will soon be found that will produce a fuel of satisfactory grade at a cost which will enable the product to compete with the higher grades of coal from Montana and the East.

AREAS IN THE SOUTHERN PORTION OF THE STATE.

The Laramie and Fort Union formations of eastern Montana extend into North Dakota, covering its southwestern portion as far as the counties of Emmons, Burleigh, and McLean, on the eastern side of the Missouri River. This area consists of a plains region with more or less deeply eroded drainage channels, along the banks of which the coal seams are exposed.

The rocks consist mainly of coarse-grained sandstones of yellow or gray color, alternating with beds of clay. The coal beds are located near the base of the measures. They vary in thickness from 4 to 14 feet where mined. At many places these beds, or some of them, have been burned, baking the adjacent sandstones and clays and giving them a reddish hue, which contrasts strongly with the prevailing yellow of the rocks.

The strata in general are horizontal, or if any inclination is observed it is very slight.

The character of the lignite varies in the different beds and in different portions of the same bed. The poorer grades consist of alternating bands of coal of fibrous structure and brownish tinge with bands having a homogeneous structure and conchoidal fracture. Other beds are composed of but one class of coal, that having a homogeneous structure. All of the coal mined for the general market is from the beds which contain the higher grade of coal.

The mines in this field are located at or near the largest settlements, the principal ones being at Lehigh, in Burleigh County, and Sims, in Morton County, both on the line of the Northern Pacific Railway, and at Wilton and Washburn, on the line of the Bismarck, Washburn and Great Falls Railway, 30 miles north of Bismarck. There are a few mines on the "Soo Line" in Emmons County, but the seams are so small that the coal can not be produced as cheaply as at the other points mentioned, and the mines merely produce enough coal to supply the demands of the immediate vicinity. Numerous other mines, located at points remote from the railway, are operated for the accommodation of the settlers in the vicinity.

The following section is from a bore hole in the vicinity of Sims, and shows a greater thickness of the coal-bearing portion of the measures than is usually found. At most points there are but two or three beds having a workable thickness.

Section of coal-bearing strata near Sims, N. Dak.

	Feet.
Bed I	8
Intervening strata	60
Bed II	5
Intervening strata	70
Bed III	5
Intervening strata	200
Bed IV	5
Intervening strata	380
Bed V	6
Intervening strata to the base of the Laramie formation	80

The coal from the mines in this area is used in the towns along the line of the railroads mentioned throughout the State, a small amount reaching the markets of western Minnesota.

MOUSE RIVER FIELD.

In the northern part of the State, on the drainage of the Mouse River, other exposures of the coal-bearing formations are found. The mines in this area are located along the line of the Great Northern Railway at Minot and the "Soo Line" at Burlington and Kenmare, all in Ward County.

The rocks at this point belong to the Laramie formation. They consist of beds of coarse-grained sandstone at the base, with numerous small bands of lignite, the upper part of the measures containing sandstones of finer texture, alternating with beds of clay. The coal beds of workable thickness are found in this portion of the measures. The beds mined vary in thickness from 2 to 8 feet.

The character of the coal is identical with that from the field in the southern part of the State. More of the seams. however, present the mixed bands of the two grades of coal.

The market for the product of this field is limited to the towns along the lines of the railways in the northern part of the State, none of it reaching west of the Montana line. At one time a little of this coal was shipped to St. Paul and Minneapolis, but it could not compete with the coals reaching those markets from the south and east, even though sold at a much lower figure.

SOUTH DAKOTA.

The only portion of South Dakota that is underlain by coal seams of importance is that along the western tier of counties, the exposures of Cretaceous measures in the southeastern portion of the State never having developed anything of value. The only operations in the area, at Ponca, Nebraska, have been given up on account of the inferior character of the coal and the thinness of the seam.

The coal-bearing formations of North Dakota and Wyoming extend across the line into South Dakota, being found in Ewing, Hardin, Martin, and Butte counties, in the northwestern portion of the State. As these counties are remote from railway communication, the field has never been thoroughly explored. The only mining operations are such as are necessary to supply the settlers with fuel. All of the coal thus far discovered is lignite.

The rim of the Cretaceous beds exposed around the Black Hills, the lowest member of which, the Dakota, has been proved to contain coal beds of economic importance to Wyoming, extends in a southeasterly direction from the State line through a portion of Butte, Meade, Pennington, Custer, and Fall River counties. These rocks have not been thoroughly explored, and as a result all of the coal for the mining camps of the Black Hills is derived from the mines operated on the western edge of these exposures in Wyoming.

No mines of economic importance are operated within the State, although without doubt there are localities where the small coal seams of the Dakota measures have a local thickening, and where mining operations could be conducted with profit.

NEVADA.

The only point in Nevada at which coal of any value has been discovered is in what is termed the Eureka field.

This area is located in central Nevada, extending south from the station of Carlin, on the line of the Central Pacific Railway, a distance of 30 miles. There are no mines in operation in the area, and the work now being done has been undertaken with the idea of determining the value of the field.

The coal-bearing strata at this point, probably Neocene lake beds, occupy the center of a narrow synclinal basin between the White Pine and Diamond ranges. Extensive movements subsequent to the formation of these ranges have badly broken the strata.

There has been but one coal bed discovered, and that is only occasionally of workable thickness, at times being 5 feet thick. The coal is lignitic and somewhat impure, resembling in external appearance the coals of the lake beds of Idaho and western Montana.

IDAHO.

No coal is mined in Idaho on a large scale, the operations being confined to the small areas of Neocene lake beds along the Snake River in the southern part of the State, all of which are in the nature of prospects. The only other known occurrences of coal are near Salmon City, in areas of the same lake beds, and at the eastern edge of the State, where the Cretaceous strata of the Sublette field of Wyoming extend across the line. At neither of these points are any mining operations carried on.

Of these areas the westward continuation of the Sublette field has been described in connection with the fields of Wyoming, and as there are no mines in Idaho the mere reference to the area at this point is sufficient. So far as known the strata in the vicinity of Salmon City, in the north-central portion of the State, contain no coal of any value, the seams all being very thin and the coal an inferior quality of lignite. The small area south of the station of American Falls, on the Oregon Short Line, has never been thoroughly prospected, hence no data are available concerning it. The areas in the vicinity of Boise are the only ones that have received sufficient attention to furnish data of any value.

BOISE AREAS.

Immediately in front of the Boise Mountains, and occupying the lower portion of the ridge between the Boise and Payette rivers, are the Neocene lake beds to which the term Payette formation has been given. The rocks have been eroded into a number of separate tracts extending north and south a distance of about 30 miles from a point 6 miles north of Boise. They consist of beds of light-colored sand, locally cemented by hot spring deposits, with occasional bands of clay. At the base of the measures near Horseshoe Bend and Jerusalem small seams of coal are to be found.

The strata of this formation rests upon the eroded surface of the granite and have but a slight inclination, with the exception of the edges near the mountains, which have a westerly dip in places as high as 50°.

But two of the areas, both located near the southern end, have developed any coal of value. These are called, respectively, the Horseshoe Bend and Jerusalem districts. In the first there is but one seam, 3 feet in thickness, the coal being a high-grade lignite. In the other district there are four seams ranging from 3 to 8 feet in thickness, the coal of the largest seam being very impure. The character of the coal is about the same in both districts. While a slightly higher grade of coal might be expected in the steeply upturned portion of the field, the beds at that point are so badly broken as seriously to interfere with operations of any magnitude.

There has not been enough development work done to establish the absolute value of these deposits, and no mines are in operation.

MONTANA.

The coal-bearing formations of this State have a greater range in the geologic scale than elsewhere in the Rocky Mountain region. This range is from the Jurassic to the Tertiary, though most of the coal is of Cretaceous age. There is a small area of Jurassic rocks which contain one seam of coal. This is not, however, of workable thickness, and the occurrence is of interest only as indicating the beginning of conditions favorable to the formation of coal during that period. The formations containing valuable coal deposits occupy the entire range of the Cretaceous, coal being found in the Cascade formation, at a lower horizon than in any of the fields south of Montana.

As in Wyoming, the plains region to the east of the Rocky Mountains, extending into the Dakotas, is underlain by beds of lignitic coal of varying quality. Westward from the plains the coal gradually changes in character. The beds adjacent to the outlying spurs contain a higher grade of lignitic coal, while in those along the base of the main range are found bituminous and coking coals.

The coal fields of Montana form a nearly continuous belt extending in a northwest-southeast direction entirely across the State. Very little detailed investigation has been made in most of these fields, however, and hence only a general idea can be given of their value. Only in a few of the fields are data as to the number of coal beds obtainable. Generally the coal beds are extremely variable, and the gradation from coal to bone or shale is very abrupt, while the coal is sometimes entirely cut out by a bed of sandstone.

BULL MOUNTAIN FIELD.

The productive measures of this field, which are probably Fort Union, lie above the formations of the surrounding plains. The underlying Laramie also contains several beds of workable thickness, though the coal is not equal in quality to that found in the higher formation. The field lies about 45 miles northeast of the town of Billings and an equal distance from the Northern Pacific Railroad.

The outcrop of the only workable coal bed outlines an elliptical area of 55 square miles, all of which contains workable coal. Extensive prospecting along the outcrop around the entire field has demonstrated the evenness of the strata, their inclination at no point being greater than 6°. The center of the basin is located a little west of the center of the field.

On the east-west axis through the center of the field the bed acquires its greatest thickness of 16 feet of clean coal, thinning down to 10 feet at the extreme western end. In the eastern portion of the field there is about the same thickness of coal, but a band of sandstone, only a few inches in thickness through the greater part of the field, separates the seam into two benches, the sandstone acquiring a maximum thickness of 50 feet.

This coal is lignitic in character, but, as shown by the accompanying analyses, is of a much higher grade than that in the underlying formations. Only a small quantity of coal is now mined in this field, as the country is almost entirely a cattle and sheep range.

CLARKS FORK FIELD.

The Bighorn Mountain uplift has brought the Laramie to the surface along its western side, forming the Clarks Fork field. It crosses the Yellowstone River 22 miles west of Billings and extends thence north to the Musselshell River. The northward extension of the field is not known to contain coal beds of value. At a point about 8 miles south of the Yellowstone River the beds acquire a workable thickness, which is maintained southward into the Bighorn Basin field of Wyoming.

The coal occupies the bottom of the Laramie formation, the "basal sandstone" being exposed but 10 feet below the lowest bed, while the bed now worked is 50 feet above. The inclination of the beds averages about 5° toward the west.

The bed which is mined varies in thickness from 5 feet at the northern end of the workable area to 3 feet about 6 miles south of this point, and again increases to nearly 5 feet within the next 15 miles.

There are two other beds at this point, one immediately above the bottom of the Laramie and another about 500 feet higher. Neither of these beds has developed a workable thickness at any of the points where they have been opened.

The coal is lignitic, but has a peculiar structure. Bands of bright coal alternate with bands having a dead appearance and closely resembling bony coal. The proportion of the latter gradually increases toward the north, where they become shale lenses, so that the product is of little value. Toward the south the coal is very bright and quite pure.

The field is reached by a branch of the Northern Pacific Railway, the principal market for the product being the mines and smelters of Butte and vicinity.

ROCKY FORK FIELD.

This field is situated only about 3 miles west of the Clarks Fork field. The coal-bearing rocks are immediately above the Laramie strata and probably belong to the Fort Union. The field lies at the base of the Beartooth Mountains, around which the Carboniferous limestones are almost vertical. The coal-bearing strata dip west, toward the mountains, at an angle of about 4°. The strata at the northern border of the field are much more steeply inclined, the dip being 21° to the south. The slope of the only producing mine in the field is driven south from this northern border, and the strata flatten rapidly in this direction, soon assuming the normal westerly dip. The field is about 6 miles in length north and south and extends eastward 5 miles from the limiting limestones of the western border.

There are five coal beds of workable thickness throughout the field. The following is an average section:

Section of coal beds in Rocky Fork field.

	Ft.	in.
Bed No. 1	5	3
Intervening shales, clays, and soft sandstones	71	0
Bed No. 2	4	11
Intervening strata	58	0
Bed No. 3	7	9
Intervening strata	40	0
Bed No. 4	4	0
Intervening strata	70	0
Bed No. 5	5	0

The coal is very similar in character to that of the Canyon City field in Colorado; it is of a transitional type between bituminous coal and lignite, making an excellent steam and domestic fuel. The only mine operated in this field is that at Red Lodge, owned by the Northern Pacific Railroad Company, a large part of the supply for their locomotives being taken from this mine. The output will soon be increased by the enlargement of the plant and the addition of a washer to handle the fine sizes that have heretofore been thrown away on account of the large amount of impurities contained.

It is probable that a connecting field will be discovered in the rough country at the base of the mountains between this field and the one located 60 miles toward the northwest, on the Boulder River.

YELLOWSTONE FIELD.

The outcrop of the coal-bearing formations can be followed 150 miles from the extreme eastern end on the Boulder River through the Boulder, Livingston-Bozeman, and Sixteenmile, and Shields river basins, thence circling around the northern and eastern end of the Crazy Mountains and connecting with the western end of the plains field.

The Boulder district comprises the area of Laramie along the drainage of the West Boulder, extending thence west as far as the Yellowstone River at Livingston. The area covered by the Coal Measures is 30 miles in length east and west, and from 5 to 18 miles in breadth. This northern border of the field is formed by the edge of the overlying Livingston formation. The strata dip north, away from the Boulder Mountains, from 12° to 45°.

Only one coal bed has as yet been discovered in this field. This has a maximum thickness of 4 feet at the eastern end, on the West Boulder River.

The coal cokes, and, although it has never been tested on a large scale, laboratory tests indicate that it is a high-grade fuel.

The Livingston-Bozeman district consists of the continuation of the Boulder district from the Yellowstone River westward.

The coal-bearing formations outcrop along the northern base of the mountains westward to the Gallatin Range, and their outcrops swing northward along the eastern base of the Gallatin and Bridger ranges. This district contains the maximum thickness of coal in the entire field, and is the only portion in which actual mining is now going on.

The strike of the beds follows very closely parallel to the neighboring mountains, the dip being everywhere away from them. Numerous minor fault planes occur where the strike of the beds makes an abrupt change in direction, and the dislocation of the strata has been further increased by the subsequent intrusion of igneous rocks.

Four coal beds have been discovered in this field, one of which never attains workable thickness. As a rule, only one bed is productive at any one point, the others having pinched down below the limit of profitable mining. The beds are composed of alternating bands of coal, bony coal, bone, and shale in varying proportions, and the gradation from one to the other is very abrupt. In several instances which have come under the observation of the writer a band of coal containing but 5 per cent of ash has changed in a distance of but 50 feet along the strike to material containing as high as 40 per cent of ash. The beds vary from 4 to 16 feet in thickness where mined, the dip varying from 25° to 90°. The only practicable method of mining consists in taking out the entire bed and passing it through a washer, the resulting product being a high grade of steam and coking coal.

There are at present two operating mines in this district, one of which has just been opened.

A large proportion of the output is consumed for locomotive fuel on the Northern Pacific Railway, the main line of which crosses the western end of the district.

The Sixteenmile Creek and Shields River districts extend northward 40 miles from the line of the Northern Pacific Railway, to the northern end of the Crazy Mountains. From this point they extend westward 45 miles, around the northern end of the Bridger Range. Along the many miles of Laramie outcrops thus exposed the coal has been prospected by a series of open cuts, which have failed to show any thickening sufficient to warrant the opening of mines and the extension of the railroad. The Cascade formation is present over a small portion of the western part of this area, and one coal bed has been found a short distance above the base of the measures, but not of workable thickness.

This great area of coal-bearing rocks offers a promising field for detailed prospecting, and coal, if found in workable thickness, will be especially valuable by reason of its proximity to the large mines and smelters of Butte and Helena.

TRAIL CREEK FIELD.

This area consists of a small synclinal basin of the Laramie, situated 9 miles south of the Northern Pacific main line at Mountain Side, and separated by only half a mile from the Yellowstone field. At the eastern edge of the field the strata are overturned along the base of a high ridge of Carboniferous rocks, from which it extends westward 4 miles, to the base of a ridge formed by an eruptive overflow from the Gallatin Range. It extends north and south along the valley of Trail Creek about 9 miles.

There are three coal beds of workable thickness throughout the northern end of the field, where there are two operating mines, in which the coal has a thickness of 4 to 12 feet.

The coal is entirely different in character from that of the Yellowstone field. It yields a large proportion of lump coal, and is semibituminous, being chiefly valuable for domestic use, while fine coal chiefly is produced at Chestnut and Mountain Side.

The production in 1900 was small, the mines having been connected with the railroad during that year.

CINNABAR FIELD.

This field extends northward from the northern border of the Yellowstone National Park, on either side of the Yellowstone River. The portion of the field on the east side of the river probably contains no workable coal.

The main portion of the field occupies the high land extending north from Electric Peak, and is 1,500 feet above the valley of the river. The coal is conveyed to the coke ovens in this valley by a long flume.

That portion of the field in which mining is now carried on consists of a series of faulted blocks, in which the beds through the southern end of the field are nearly horizontal. The field extends from the high bluffs overlooking the Yellowstone westward 3 miles to the deeply eroded valley of Cinnabar Creek. Along the northern border the strata are steeply upturned against the base of Cinnabar Mountain.

There are four coal beds in the main portion of the field, all of which are of workable thickness, the thickest being 5½ feet. The coal has all been highly altered by the eruptive rocks of Electric Peak, several intrusive sheets from which have invaded the coal-bearing rocks. The coal from three of the beds makes a good grade of coke, that of the other bed being semianthracite, very hard, and having the characteristic luster and cleavage of anthracite.

There is but one mine operated in the field, a part of its product being converted into coke. The plant has been considerably enlarged during the last year, and its capacity is at present much larger than in 1900. The field is reached by the Park branch of the Northern Pacific Railway.

WEST GALLATIN FIELD.

Along the headwaters of the West Gallatin River and between the Gallatin and Madison ranges there are several isolated areas of the

Laramie formation. Their location, however, is so remote that little attention has hitherto been given to the coal.

The only one of the several areas in which coal of value has been found is on Taylors Fork of the West Gallatin, 75 miles from the Northern Pacific, at Bozeman. This area occupies the high divide between the West Gallatin and Madison rivers. It forms a synclinal basin 6 miles across, with dips on the northern margin of 20° and on the southern margin of 6°.

There are three coal beds in this field, ranging from 4 to 6 feet in thickness. The character of the coal is still in doubt, as none of the development work has exposed any of the beds to a sufficient depth to get beyond the effects of weathering. At some points one of the beds shows a pronounced coking quality, which is probably the character of the coal throughout the area. The other areas in this region offer promising fields for detailed prospecting. Owing to the proximity of large bodies of eruptive rock, the coals will doubtless be found highly altered. These areas are located on the West Fork of the West Gallatin and immediately north of the Sphinx Mountain.

RUBY VALLEY FIELD.

This field is located 30 miles west of the Gallatin field, and has received even less attention than the latter. The rocks are of Laramie age, and do not present any indications of serious disturbance. The only prospecting done in this field consists of a series of open cuts along the outcrop. These have as yet failed to develop beds of workable thickness.

TOSTON AREA.

There is an isolated area containing 6 square miles of the Cascade formation 3 miles south of the town of Toston and crossed by the main line of the Northern Pacific. The strata are badly broken and the field is so small that the erection of a large mining plant would not be warranted. The field could doubtless be operated with profit on a small scale, especially as the coal is coking. There are portions of the bed in which the coal has been altered beyond the coking stage and is essentially graphite.

SMITH RIVER AREA.

This area lies along the high divide east of the Smith River. It is so remote from transportation that no attention has been given to its development, and there is no information obtainable regarding the coal which it may contain.

BELT FIELD.

This field lies along the northern base of the Little Belt Mountains and their westward extension on the west side of the Missouri River, extending westward 125 miles from the Judith River. The country underlain by the coal is so deeply covered with glacial drift that the strata are exposed only along the canyon walls. The field is a narrow belt extending along the base of the mountains, its strata having a slight dip toward the north, away from the range. This is the only considerable occurrence in the United States of the Kootenai formation of the Canadian coal fields. This formation has been named the Cascade by Mr. Weed. The only coal bed of workable thickness is near the center of the formation. The thickest point seems to be in the vicinity of the mines at Sandcoulée. Northward from this point the bed thins out, while toward the west it splits into two benches separated by a bed of shale reaching a thickness of 25 feet. At Sandcoulée the coal is 7½ feet in thickness, with three small shale partings. The coal from the various bands is quite different in character, that from the bottom being coking and containing the smallest amount of ash, while that from the other two benches does not exhibit any tendency to coke, but makes an excellent steam fuel. The only objectionable feature is the excessive amount of ash contained in the middle bench. Near the mouth of Smith River and on Hound Creek the bed is betwen 5 and 6 feet in thickness.

The extension of this field west of the Missouri River has never been thoroughly prospected. At some points the coal shows a workable thickness along the outcrop, and future prospecting will doubtless develop a valuable productive area. The coal has been opened at a number of places in the eastward extension of the field through the Judith Basin. The fuel for the town of Lewiston is obtained from mines at the base of the Judith Mountains.

The output of these mines is used in their immediate vicinity, since this part of the field has no railroad connection. The mines of the Great Falls district are on a branch of the Great Northern Railway. Their output is largely coked in the ovens at Belt.

SWEETGRASS HILLS FIELD.

This field is located on the eastern slope of the foothills of the Rocky Mountains, in the extreme northern portion of Montana. The coal occurs in the Belly River formation, which extends south from Canada. But little development has been done in this field and there are no producing mines. There are three coal beds of workable thickness exposed which are capable of yielding a fair grade of semibituminous steam coal.

AREAS OF THE LAKE BEDS.

Along the summit of the main Rocky Mountain range and westward there are numerous areas of Neocene lake beds which contain some lignitic coal. None of these areas have as yet developed any coal of value.

The rocks of some of these areas were deposited in basins in the granite, and others upon more recent beds. They form a series of isolated basins distributed over a region which extends westward 90 miles from the Continental Divide and southward into Idaho. They are probably to be correlated with the areas at the base of the Boise Mountains. There are several points at which these lake beds have been subjected to the influence of the later eruptions, and further prospecting may develop coal of a higher grade than that thus far discovered.

PRODUCTION.

Relation of production to capacity of mines for the Rocky Mountain coal fields in 1900.

State.	Number of counties producing coal.	Number of commercial mines.	Production, 1900.	Estimated capacity of mines, 1900.	Ratio of production to capacity.	Mines reporting prospective increase of capacity.
			Short tons.	*Short tons.*	*Per cent.*	*Per cent.*
North Dakota	6	36	129,883	172,408	75.3	2
Montana } Idaho }	10	29	1,661,780	2,602,068	63.8	15
Wyoming	10	30	4,014,602	7,082,512	56.6	10
Utah	6	35	1,147,027	2,005,963	57.1	4
Colorado	19	116	5,244,364	7,162,092	73.2	8
New Mexico	7	31	1,299,299	2,050,646	63.3	6

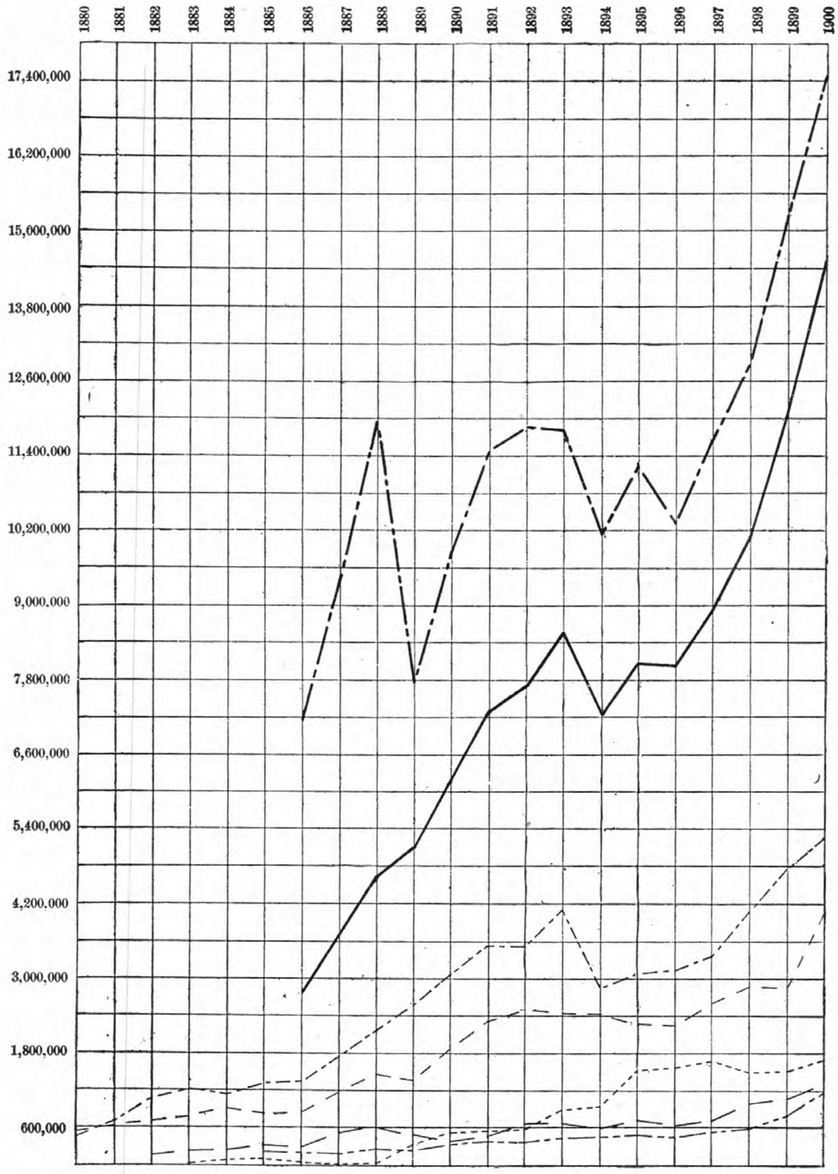


FIG. 36.—Production and value of coal in the Rocky Mountain fields from 1880 to 1900.

Montana. Wyoming. Colorado. New Mexico. Utah. Total production. Total value.

Scale {600,000 tons to the square. $600,000 to the square.

Production and distribution of product of the Rocky Mountain coal fields for 1900.

Subdivision of fields.	Production.	Value at mines.	Average value per ton.	Railroad fuel.		Steamboat fuel.	
				Quantity.	Per ct.	Quantity.	Per ct.
	Short tons.			*Short tons.*		*Short tons.*	
North Dakota	129,883	$158,348	$1.22	6,240	4.8	0	0
Montana, Idaho	1,661,780	2,713,757	1.63	522,291	31.4	0	0
Wyoming	4,014,602	5,457,953	1.36	1,996,440	49.7	7,500	0.2
Utah	1,147,027	1,447,750	1.26	417,500	36	0	0
Colorado	5,244,364	5,858,036	1.12	1,348,140	25.7	0	0
New Mexico	1,299,299	1,776,170	1.37	589,806	45.4	0	0
Total	13,496,955	17,412,014	1.29	4,880,417	35.1	7,500	.06

Subdivision of fields.	Manufacturing fuel.		Domestic fuel.		Made into coke.	
	Short tons.	Per cent.	Quantity.	Per cent.	Quantity.	Per cent.
			Short tons.		*Short tons.*	
North Dakota	25,241	19.4	98,402	76.8	0	0
Montana, Idaho	590,696	35.6	415,138	25	133,655	8
Wyoming	1,184,620	29.5	793,582	19.9	32,460	.7
Utah	395,798	34.9	305,430	27.1	28,299	2
Colorado	1,374,975	26.3	1,550,759	30	970,490	18
New Mexico	121,080	9.4	561,080	43.2	27,333	2
Total	3,692,410	28.5	3,724,391	27.34	1,192,237	9

Development of the Rocky Mountain coal fields, by decennial periods.

State.	1880.			1890.		
	Production.	Value.	Average price per ton.	Production.	Value.	Average price per ton.
	Short tons.			*Short tons.*		
North Dakota	0	0	......	30,000	$42,000	$1.40
Montana, Idaho	224	$800	$3.57	517,477	1,252,492	2.42
Wyoming	589,595	1,080,451	1.83	1,870,366	3,183,669	1.70
Utah	14,748	33,645	2.27	318,159	552,390	1.74
Colorado	462,747	1,041,350	2.25	3,094,003	4,344,196	1.40
New Mexico	0	0	......	375,777	504,390	1.34

Development of the Rocky Mountain coal fields, by decennial periods—Continued.

State.	Increase of 1890 over 1880.			
	Product.	Per cent.	Value.	Per cent.
	Short tons.			
North Dakota	30,000	....	$42,000	....
Montana, Idaho	517,253	230,916	1,251,692	156,462
Wyoming	1,280,771	217	2,103,218	194
Utah	303,411	2,057	518,745	1,542
Colorado	2,631,256	569	3,302,846	317
New Mexico	375,777	....	504,390	....

State.	1900.			Increase of 1900 over 1890.			
	Production.	Value.	Average price per ton.	Product.	Per cent.	Value.	Per cent.
	Short tons.			*Short tons.*			
North Dakota	129,883	$158,348	$1.22	99,883	333	$116,348	277
Montana, Idaho	1,661,775	2,713,707	1.63	1,144,298	221	1,461,215	116
Wyoming	4,014,602	5,457,953	1.36	2,144,236	115	2,274,285	71
Utah	1,147,027	1,447,750	1.26	828,868	261	895,360	162
Colorado	5,244,364	5,858,036	1.12	2,150,361	70	1,513,840	35
New Mexico	1,299,299	1,776,170	1.37	923,522	241	1,271,780	252

THE COAL FIELDS OF THE PACIFIC COAST

BY

GEORGE OTIS SMITH

CONTENTS.

ILLUSTRATIONS.

THE COAL FIELDS OF THE PACIFIC COAST.

By George Otis Smith.

INTRODUCTION.

The coals of the Pacific coast States are all of Tertiary age and in great part of the character termed lignitic. The coal formations have not been traced over large areas, so that the coal fields are limited in extent and widely separated. This feature necessitates separate discussion of the fields, which, however, are grouped according to States.

Of the three States, Washington easily ranks first as a coal producer, while California at the present time stands second, although a few years ago Oregon's output exceeded that of California.

The following table shows the production, by States, since 1885. The vicissitudes of the coal industry of the several States are indicated in this table. Especially noteworthy is the increase in California's output in the last five years, with a somewhat proportionate decrease in the coal production of Oregon. The steady increase by which the production of Washington has been more than doubled in this same period should also be noted.

Production of coal on the Pacific coast since 1885.

[Short tons.]

Year.	California.	Oregon.	Washington.
1883	76,162		
1884	77,485		
1885	71,615	50,000	380,250
1886	100,000	45,000	423,525
1887	50,000	37,696	772,601
1888	95,000	75,000	1,215,750
1889	121,820	64,359	1,030,578
1890	110,711	61,514	1,263,689
1891	93,301	51,826	1,056,249
1892	85,178	34,661	1,213,427
1893	72,603	41,683	1,264,877
1894	67,247	47,521	1,106,470
1895	75,453	73,685	1,191,410
1896	78,544	101,721	1,195,504
1897	85,992	107,289	1,434,112
1898	144,288	58,184	1,884,571
1899	160,715	86,888	2,029,881
1900	171,708	58,864	2,447,629

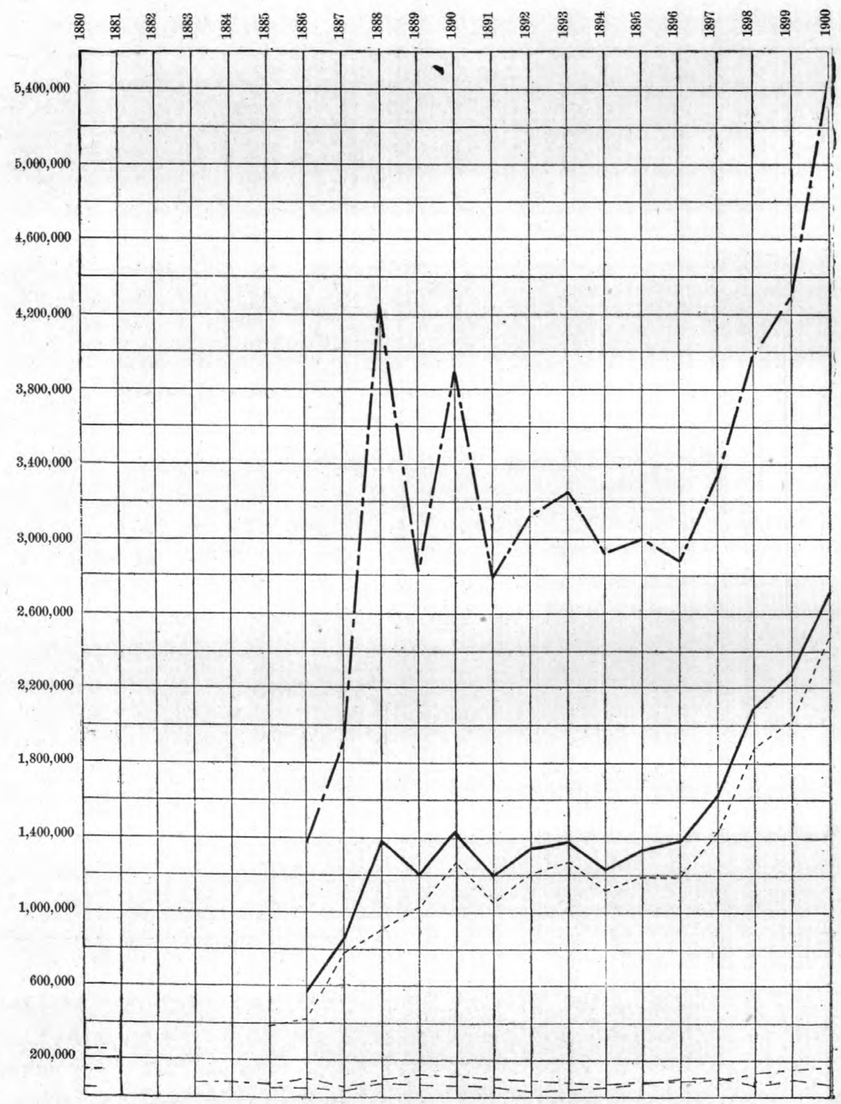


FIG. 37.—Production of coal in the Pacific coast fields from 1880 to 1900.

- - - - - - Washington. ——— ——— Oregon. —·—·—·- California. ———— Total production. ——— - ——- Total value.

Scale {200,000 tons to the square. $200,000 to the square.

Development of the Pacific coast coal fields by decennial periods.

State.	1880.			1890.		
	Production.	Value.	Average price per ton.	Production.	Value.	Average price per ton.
	Short tons.			*Short tons.*		
Washington	145, 015	$389, 046	$2. 68	1, 263, 689	$3, 426, 590	$2. 71
Oregon	43, 205	97, 810	2. 26	61, 514	177, 875	2. 89
California	236, 950	663, 013	2. 62	110, 711	283, 019	2. 56

State.	Increase of 1890 over 1880.			
	Production.	Per cent.	Value.	Per cent.
	Short tons.			
Washington	1, 118, 674	771	$3, 037, 544	781
Oregon	18, 309	42	80, 065	82
California	[a]126, 239	114	379, 994	134

State.	1900.			Increase of 1900 over 1890.			
	Production.	Value.	Average price per ton.	Production.	Per cent.	Value.	Per cent.
	Short tons.			*Short tons.*			
Washington	2, 474, 093	$4, 700, 068	$1. 90	1, 210, 404	96	$1, 273, 478	37
Oregon	58, 864	220, 001	3. 74	[a]2, 650	5	42, 126	24
California	171, 708	523, 231	3. 05	60, 997	55	240, 212	85

[a] Decrease.

The condition of the coal trade on the Pacific coast may be best studied by examination of the sources of the coal consumed in California. In the San Francisco market the coals of the world compete, and the relative importance of this or that source varies from year to year in accordance with somewhat complex laws of supply. Foreign coal enters this port chiefly as ballast in tramp steamers seeking grain cargoes, so that the condition of the wheat export trade has a direct bearing upon the coal imports. The foreign countries contributing to the coal supply of California are England, Wales, Scotland, Australia, and Japan, in addition to British Columbia, which has always been a principal source for imported coal. The imports of coal delivered at San Francisco and other California ports have amounted for a number of years to about three-fourths of the aggregate tonnage imported into the United States. These foreign coals are of better quality than the coal from the three Pacific States and command the highest prices. Eastern coals reach the Pacific coast only in small quantities, while the Rocky Mountain field has not been a source of supply for twenty years. In view of the expense of railroad transportation of the coals from the Rocky Mountains, it appears doubtful if the superior quality of these coals is sufficient to enable them to successfully enter the California market.

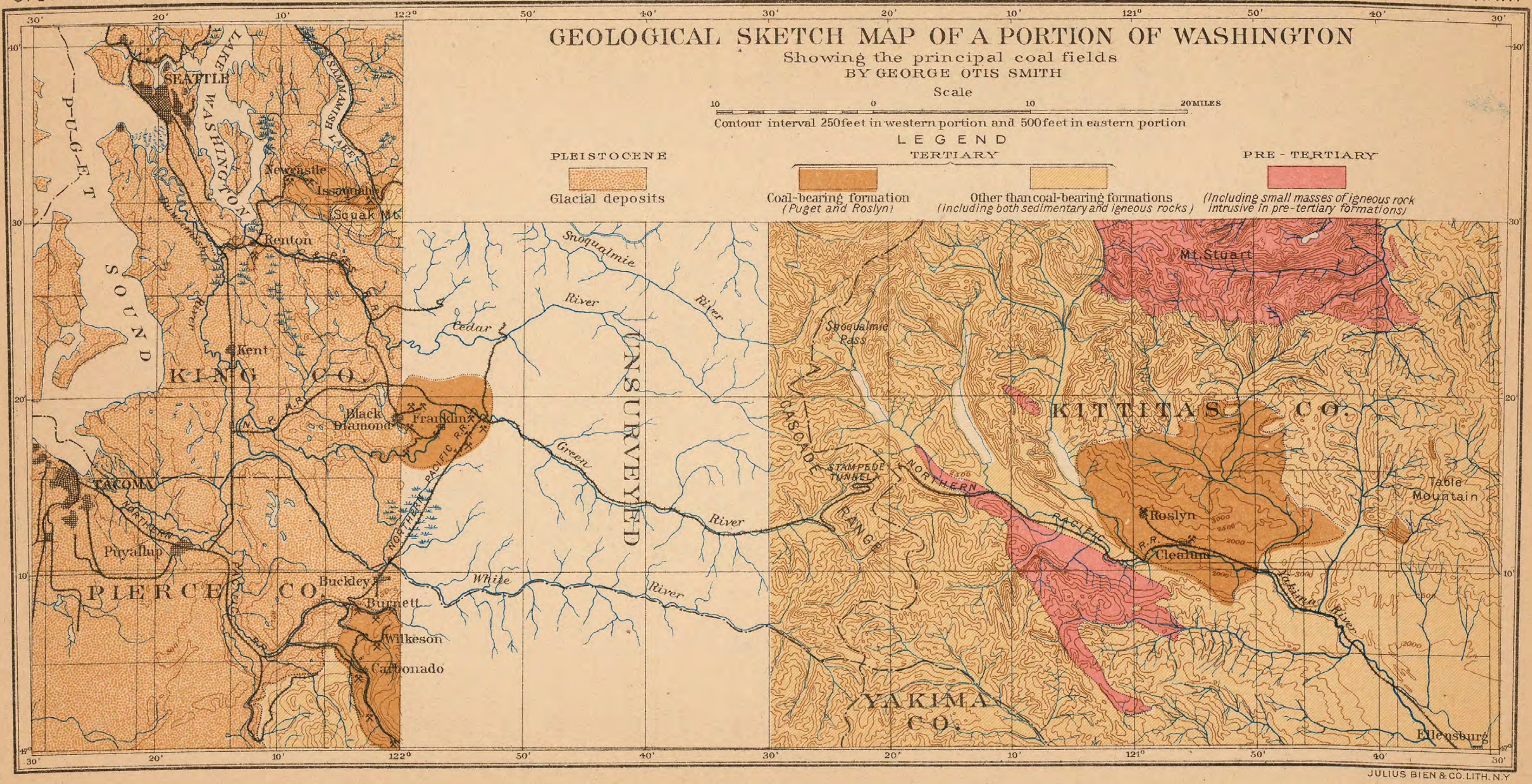
The following table contains the most authoritative data available relative to the origin of the coal supply of the largest of the Pacific States. The decrease in importance of the foreign sources, except British Columbia, should be noted, since it is the most encouraging feature of the coal industry of the Pacific States. The domestic coal resources are being developed as they deserve, with the result that while the contribution to the San Francisco market from Washington, Oregon, and California in 1861 was less than 20,000 tons, the receipts from the collieries in these three States the present year will doubtless closely approach the million-ton mark.

Sources of coal consumed in California.

[Short tons.]

Source.	1883.	1884.	1885.	1886.	1887.	1888.
Foreign	327,440	320,448	397,635	467,957	262,865	406,085
British Columbia	128,503	291,546	224,298	253,819	252,810	304,916
Washington	323,335	302,473	281,796	213,565	537,369	564,148
Eastern	43,861	38,124	29,834	19,517	21,709	30,120
California	76,162	77,485	71,615	90,664	50,000	81,194 (California and Oregon)
Oregon	....	5,000	18,161	42,168	30,240	
Total	899,301	1,035,076	1,023,339	1,087,690	1,154,993	1,386,463

Source.	1889.	1890.	1891.	1892.	1893.	1894.
Foreign	351,503	245,167	542,302	554,060	379,853	403,568
British Columbia	381,460	441,759	652,657	554,600	588,527	647,110
Washington	390,628	407,869	374,980	383,320	428,985	395,173
Eastern	23,182	32,550	42,210	35,720	18,960	16,640
California and Oregon	49,770	74,210	90,684	66,150	63,460	65,263
Total	1,196,543	1,201,555	1,702,833	1,593,850	1,479,785	1,527,754


GEOLOGICAL SKETCH MAP OF A PORTION OF WASHINGTON
Showing the principal coal fields
BY GEORGE OTIS SMITH
Scale
10 0 10 20 MILES
Contour interval 250 feet in western portion and 500 feet in eastern portion
LEGEND
PLEISTOCENE
Glacial deposits
TERTIARY
Coal-bearing formation (Puget and Roslyn)
Other than coal-bearing formations (including both sedimentary and igneous rocks)
PRE-TERTIARY
(Including small masses of igneous rock intrusive in pre-tertiary formations)
SEATTLE
LAKE WASHINGTON
SAMMAMISH LAKE
PUGET SOUND
Newcastle
Issaquah
Squak Mt.
Renton
Kent
KING CO.
Black Diamond
Franklin
TACOMA
Puyallup
PIERCE CO.
Buckley
Burnett
Wilkeson
Carbonado
Snoqualmie River
Cedar River
Green River
White River
UNSURVEYED
NORTHERN PACIFIC R.R.
Snoqualmie Pass
CASCADE RANGE
STAMPEDE TUNNEL
Mt. Stuart
KITTITAS CO.
Roslyn
Cle Elum
Table Mountain
Yakima River
YAKIMA CO.
Ellensburg
122°
121°
JULIUS BIEN & CO. LITH. N.Y.

Sources of coal consumed in California—Continued.

Source.	1895.	1896.	1897.	1898.	1899.	1900.
Foreign	483,253	440,822	400,303	308,662	260,986	275,335
British Columbia	651,295	551,852	558,372	651,208	623,133	766,917
Washington	407,155	384,842	506,380	632,437	627,450	668,642
Eastern	26,863	17,907	21,335	37,560	38,951	17,319
California } Oregon }	84,954	110,237	115,150	172,506	189,507	160,915
Total	1,653,520	1,505,660	1,601,540	1,802,373	1,740,027	1,889,128

WASHINGTON.

GEOGRAPHIC RELATIONS.

The coal fields of Washington are confined to the western and central portions of the State. Four large fields may be mentioned: The northern and southern Puget Sound coal fields, the Roslyn Basin, and the southwestern field in Lewis and Cowlitz counties. The boundaries of the coal fields of western Washington are more or less indefinite, owing to the thick mantle of glacial deposits in this part of the State. In the same way the southern Puget Sound field is subdivided into a number of districts, separated by gravel-covered areas. While these are undoubtedly parts of the same coal field, the subdivisions must be considered in the following discussion.

The northern Puget Sound coal field includes the coal mines of Skagit and Whatcom counties, in the northwestern part of the State. The southern Puget Sound field is situated in King and Pierce counties and includes that portion of the Puget Sound Basin directly east of the cities of Seattle and Tacoma. Coal is mined in 10 townships in different parts of this area, and in point of production this is the most important field of the State. Districts included in this field are the Wilkeson-Carbonado district, in Pierce County, and the Green River, Renton-Cedar River, and Newcastle-Issaquah districts of King County. The other field of western Washington lies about 40 miles southwest of the last-mentioned field and might well be considered as a continuation of it. This field includes mines that have been worked to a small extent in the past, but never with an output at all comparing with that of the other fields.

The Roslyn coal field is situated in Kittitas County, near the center of the State, and on the eastern slope of the Cascade Mountains. The outlines of this coal basin are quite definitely determined. The geographic relations of this field to the southern Puget Sound field can be seen on Pl. XXXI, which also indicates the subdivisions of the latter field.

Extensions of all the coal fields of western Washington will doubtless be discovered in the future. It is only in the canyons of the principal streams that the coal-bearing formations are exposed, and over the terraced plateaus the gravels effectually conceal the underlying rocks. Except where the forest has been cleared, the dense tangle of underbrush and thick cover of humus add to the difficulties of prospecting for coal.

GEOLOGIC RELATIONS.

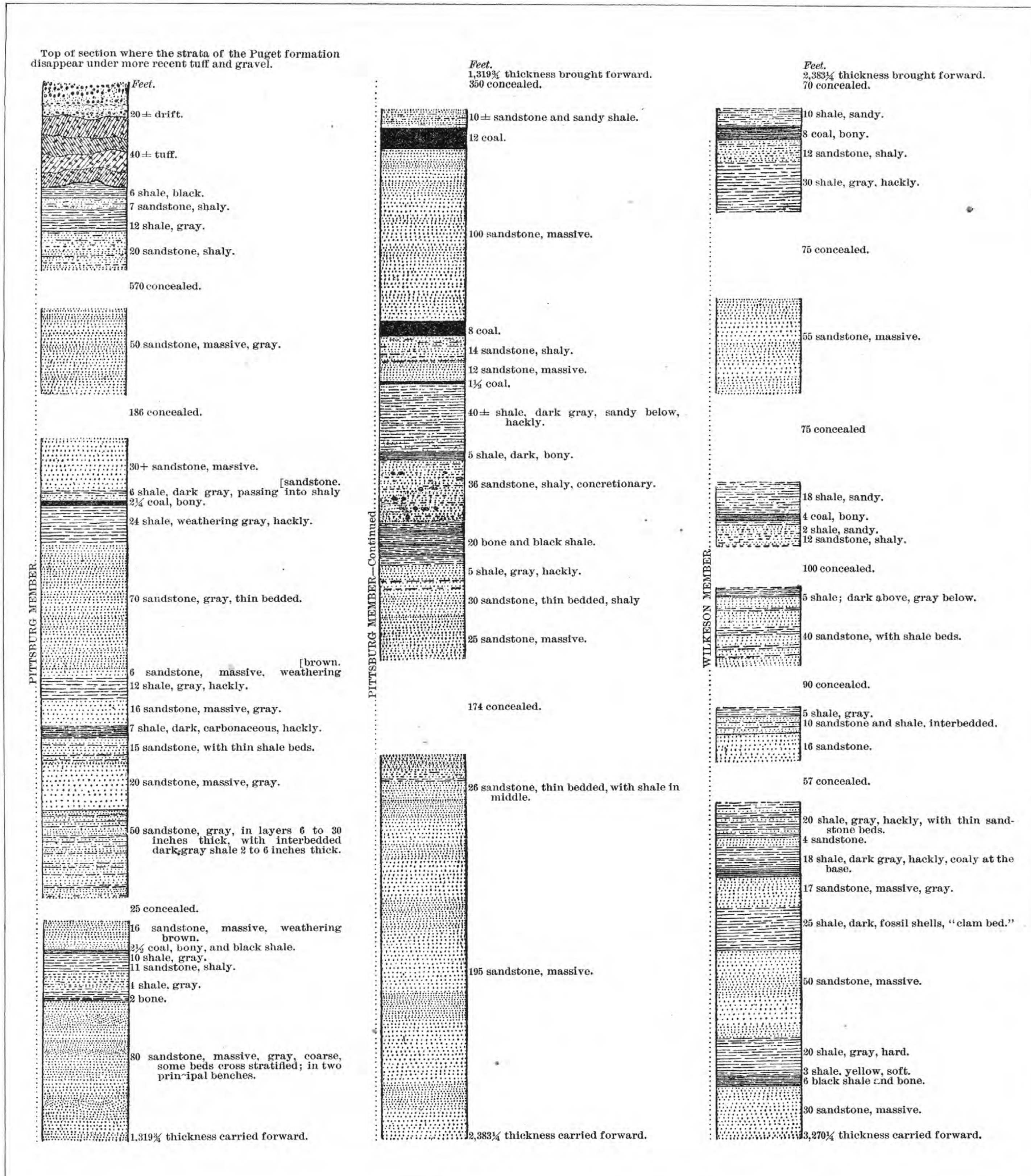
AGE OF COAL-BEARING ROCKS.

As far as known, the coal formations of Washington are of Eocene age. The rocks associated with the coal beds are very rich in fossil plants, and the study of this flora quite definitely determines the age as Eocene. The similarity between the fossil plants found in the rocks of the Puget formation in the western coal fields and those occurring in the Roslyn formation east of the Cascade Mountains affords a basis for a correlation of the two coal-bearing formations as of approximately the same age. The Puget formation doubtless represents a longer epoch of time, as shown both by the variation in its flora at different horizons and by the much greater thickness of sediments as compared with the Roslyn formation.

STRATIGRAPHY.

The Puget formation, as exposed in the southern Puget Sound coal field, consists of interbedded sandstones, shales, and coal beds, with a total thickness of 10,000 feet. The sandstones are commonly of arkose composition, while the shales are siliceous, grading into carbonaceous beds. At no point in this field is the base of the formation exposed. The coal beds of economic importance occur mostly in the lower 2,000 feet of the formation, and in the southern district of this field three members may be recognized in the Puget formation, namely: (1) The comparatively barren uppermost member, the Pittsburg, measuring 7,000 feet or more; (2) the Wilkeson sandstones, 1,000 feet in thickness, and (3) the Carbonado member, containing the important coal beds. The best section of the Puget formation is that exposed in the Carbon River Canyon, and represented on Pls. XXXII and XXXIII. The upper members are more completely exposed along South Prairie Creek, where at least 8,000 feet of strata are exposed.

In the Green River district the stratigraphy is somewhat like that of the Wilkeson-Carbonado field, in that the upper member of the



COLUMNAR SECTION OF THE PUGET FORMATION, MEASURED IN CARBON RIVER CANYON, NORTHWEST OF CARBONADO; CONTINUED ON PLATE XXXIII. (BAILEY WILLIS, 1896.)

series is generally barren and contains fossils corresponding to those obtained from the Pittsburg member on South Prairie Creek. In the Renton-Cedar River and Newcastle-Issaquah districts, farther north, complete sections have not been measured, and conditions are not favorable for correlations between these districts, or even between parts of the same district.

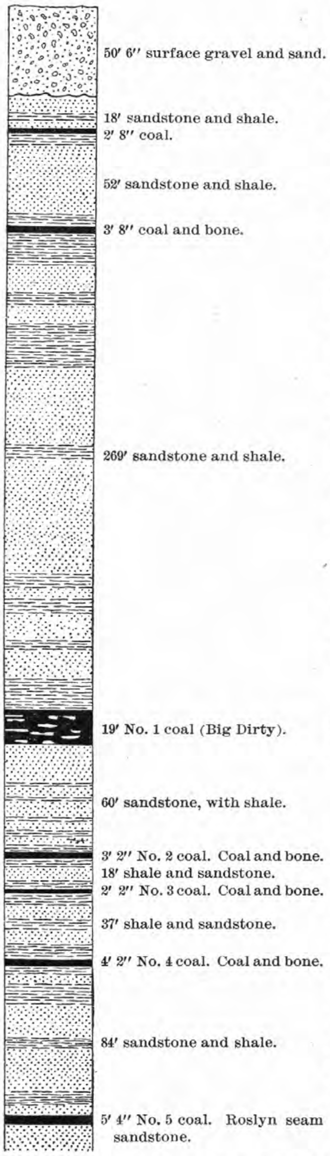


FIG. 38.—Columnar section of upper portion of Roslyn formation at the Roslyn mine.

In the northern Puget Sound field the coal-bearing formation, also of Eocene age, is known, at Hamilton and Cokedale, in Skagit County, and at Whatcom Lake, in Whatcom County, to rest directly upon metamorphic schists, and at all of these localities the coal beds are found close to the base of the formation, the schist, indeed, being reported as forming the foot wall in the mine of the Skagit Coal and Coke Company at Cokedale, while at the Blue Canyon mine only a thin bed of conglomerate lies between the schist and the coal. Sandstones and shales similar to those of the southern field constitute the coal-bearing formation of this field.

In the southwestern field the coal beds are reported as occurring in rocks resembling those of the other fields.

In the coal field east of the Cascades the coal beds are found in the upper portion of the Roslyn formation, which has a total thickness of about 3,500 feet. Fig. 38 shows this productive portion of the Roslyn formation, which throughout is characterized by sandstones less arkose in nature than those of the Puget formation. These sandstones and shales contain Eocene plants and rest upon the Teanaway basalt, which is also of Eocene age. Prospect work has been carried on in a basin 5 and 10 miles south of Clealum, on Taneum and Manastash creeks, but the formation (Manastash) exposed here, while of Eocene age, is younger than the Roslyn, and the carbonaceous beds are quite different in character.

STRUCTURE OF THE DIFFERENT FIELDS.

In the northern field little is known of the structure of the coal-bearing rocks. On Bellingham Bay the coal bed dips about 35° NW., and a similar attitude is reported for the coal on the north side of Whatcom Lake, while at Cokedale, at the south end of the lake, the coal bed is vertical. On Skagit River the coal-bearing formation occurs folded against the underlying schist to the east.

The southern Puget Sound field is characterized by a series of parallel folds, having a general north-south trend. In the Wilkeson-Carbonado district a principal arch with northern pitch passes through Wilkeson and Burnett. The principal workings of the Wilkeson mines are on the west dip of this arch and the Burnett mine is on the east dip. West of this main arch are smaller parallel arches with coal basins, the axes of which also pitch somewhat west of north. The Carbon Hill mines take their coal from these basins, while the coal beds are mined farther south on Carbon River, at Fairfax, on southern extensions of these same folds.

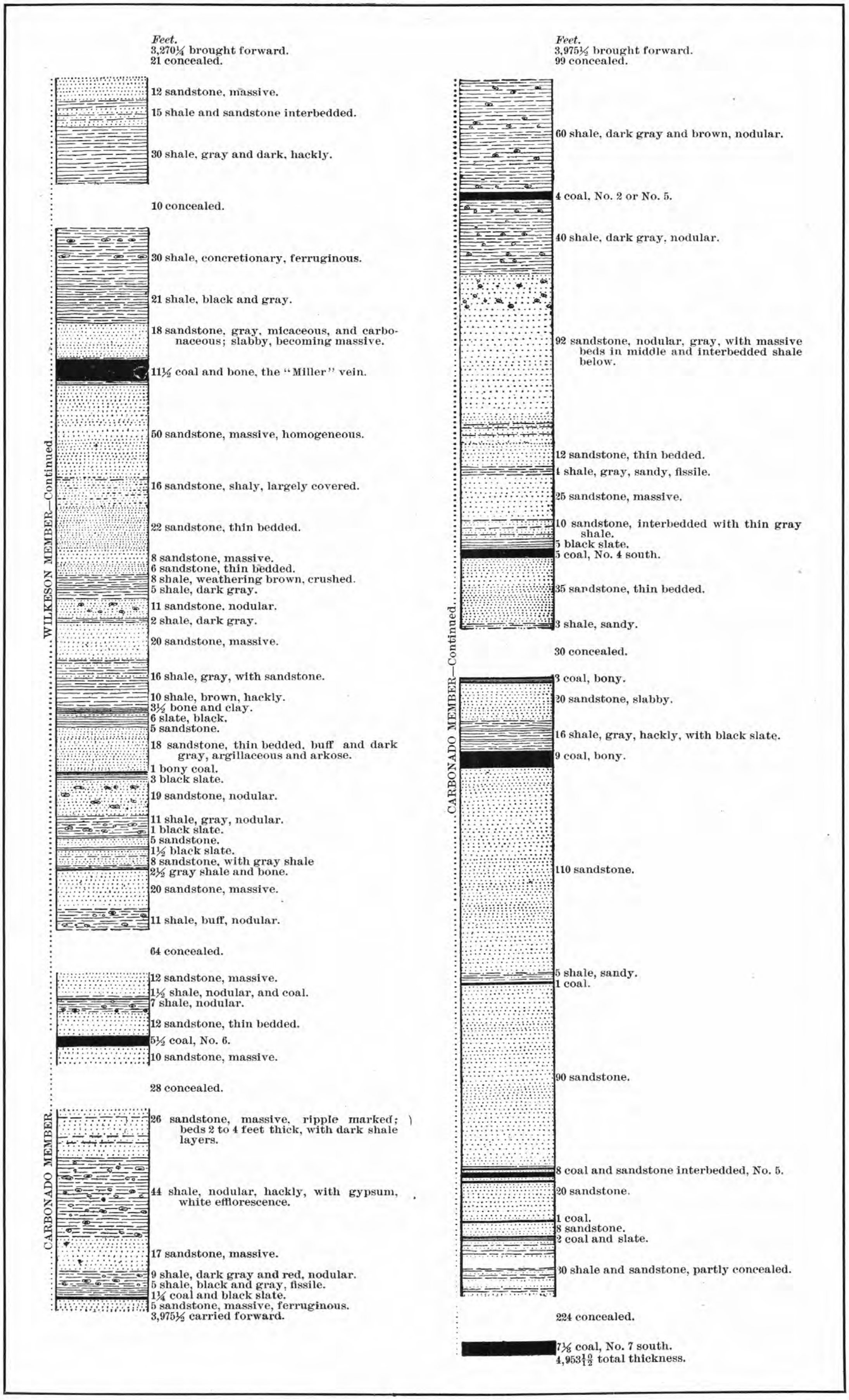
Other structural features of this district are the overthrust faults along the western side of the Wilkeson arch, encountered in the Wilkeson and Burnett mines, and the normal fault which displaces the coal beds in the vicinity of the river at Carbonado. Smaller faults causing local crushing and displacement of the coal seams are also encountered in the mines of this district.

In the Green River district the structure is less complex. The folds are more open and consist of the McKay or Franklin Basin, which opens toward the southwest, succeeded on the west by the Green River anticline, and that by the coal basin in which the Palmer and Cumberland mines have been opened. East of the McKay Basin is an anticline, on the east flank of which are the Black Diamond mines. Small faults occur in this district, but these, too, show that there has been less disturbance here than in the Wilkeson-Carbonado district.

The Renton-Cedar River district is probably a continuation of the Green River district, the folds at Renton having a southeastern trend and the coal beds being also found at Cedar Mountain and Leary, which are localities between Renton and Black Diamond. Thick deposits of drift conceal the rocks in this area so as to prevent the tracing of this connection between these two districts.

The Newcastle-Issaquah district is the most northern portion of this field. At Issaquah the coal beds dip from 20° to 40° to the north, and the same fold appears to extend to Newcastle, 5 miles farther west. The structure of this district is possibly directly connected with the occurrence of the igneous rock forming the mass of Squak Mountain.

The coal field of central Washington differs in many respects from



COLUMNAR SECTION OF THE PUGET FORMATION, MEASURED IN CARBON RIVER CANYON; CONTINUED FROM PLATE XXXII.

the fields of western Washington. The hill slopes are not masked with glacial deposits, so that only in the valleys are the coal-bearing strata concealed. The structure of the Roslyn field therefore can be determined as a simple basin, as outlined on Pl. XXXI. The axis of this basin pitches southeast, and as the fold is unsymmetrical, with low dips on its northern side, the axis of the fold is nearer the southern edge of the basin. The upper or productive portion of the Roslyn formation has been eroded except in the center of the basin, so that the coal field is limited to the immediate valley of the Yakima between Ronald and Teanaway. The deepest portion of the basin is probably near the line of the Northern Pacific Railway near Clealum. The dip of the coal beds is low, 10° to 20°, and the basin is without faults.

THE COAL.

NUMBER OF WORKABLE BEDS.

The number of coal beds in the Puget formation is remarkable. In some parts of the southern Puget Sound field over 100 coal seams may be found of thickness and quality sufficient to attract the attention of a prospector, and the workable beds in a single district may vary from five to ten in number. The number and position of such beds are partly represented in the stratigraphic sections shown on Pls. XXXII and XXXIII, while typical sections of the principal productive beds are given in the accompanying figures (figs. 39 to 46). These beds, however, show great variations in different parts of the districts where they are mined.

At Wilkeson four seams of coal are mined at depths of 200 to 800 feet below the surface. These seams are numbered 1, 2, 3, and 7, and sections of them are given in figs. 39 to 42. At Carbonado several seams have been mined, the principal one being No. 1, or the Wingate, and figs. 43 to 45 show the variation in this coal bed within a total distance of about 13,000 feet. At Burnett the Burnett No. 1 or South Prairie seam, as now worked, is 3 feet 4 inches thick. This seam is probably the same as the Wingate on Carbon River, and a section of it as exposed at the slope of the South Prairie mine is given in fig. 46.

In the Green River field three coal seams are being mined at present, known as No. 12, the McKay or White Ash, and the Gem. These seams vary from 3 to 6 feet in thickness, and are worked at depths varying from 1,000 to 2,800 feet. Higher in the formation another bed of coal is mined at the Kummer clay mine by the Denny Clay Company. In the eastern extension of this field, at Palmer and Cumberland, the McKay seam is also mined, and eight workable seams are reported.

At Renton three productive coal seams are known, the lowest of which is the Talbot, 7½ feet thick, while No. 2 is about 8 feet thick,

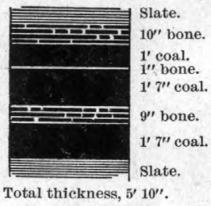


FIG. 39.—Section of Wilkeson seam No. 1.

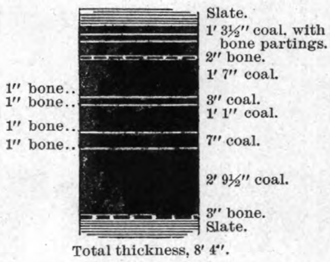


FIG. 40.—Section of Wilkeson seam No. 2.

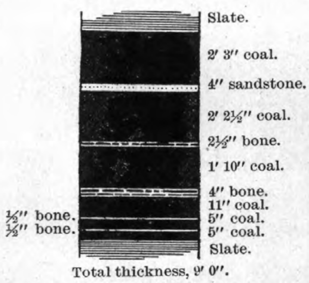


FIG. 41.—Section of Wilkeson seam No. 3.

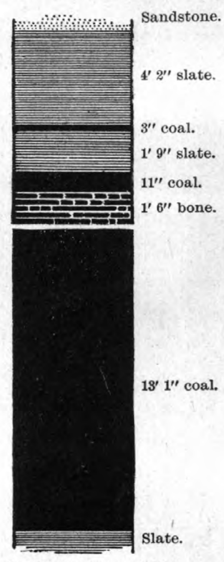


FIG. 42.—Section of Wilkeson seam No. 7, or Kelly.

(Near north end of mine No. 6, North.)

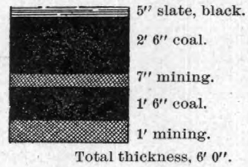


FIG. 43.—Section of Wingate seam, first section.

(11,200 feet south of first section.)

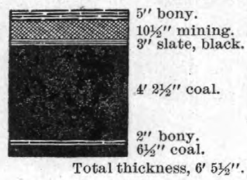


FIG. 44.—Section of Wingate seam, second section.

(1,950 feet south of second section).

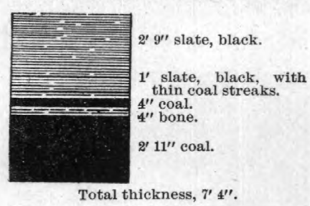


FIG. 45.—Section of Wingate seam, third section.

(At the slope.)

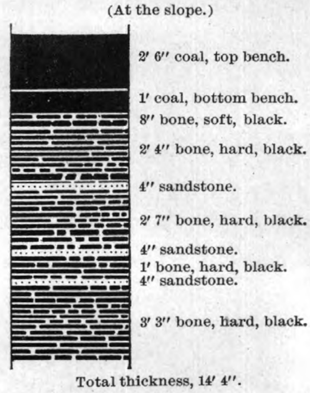


FIG. 46.—Section of Burnett seam, No. 1.

the exact thickness of the third not being known. At Cedar Mountain, 6 miles southeast of Renton, two seams, 13 feet and 3½ feet thick, have been found and worked in the past.

In the Newcastle area there are four productive seams, from 4 to 12 feet thick, which have been worked to a depth of 2,000 feet. At Issaquah six coal beds have been encountered in the mine workings, measuring from 4½ to 15½ feet in thickness. Correlations of these seams with those at Newcastle have not been made, although there are certain resemblances between the coal beds of the two parts of the district.

In the northern field the old Bellingham Bay seam was 14 feet thick, but this thickness includes much slate and bone in the upper half. The coal seam worked at present at Cokedale varies greatly in thickness, in places being 20 feet thick. The Blue Canyon seam has an average thickness of 7 feet.

In the Roslyn Basin several coal beds are known, two of which are mined. The thickness of clean coal is 4 feet 6 inches at Roslyn and 4 feet 2 inches at Clealum The coal is 640 feet beneath the surface at the Roslyn shaft and 250 feet at the Clealum shaft. Another workable seam found in this field is the "Big Dirty," 19 feet in thickness and 200 feet above the Roslyn seam. The Clealum seam is believed to overlie all of the five coal beds cut by the Roslyn shaft, while a hole put down for 800 feet below the Roslyn seam did not show any coal beds exceeding 18 inches in thickness.

CHARACTER OF THE COAL.

The coals of Washington range from lignite to bituminous coking coal. Even within the principal field the variations in composition of the coal are considerable, the moisture ranging from less than 1 per cent to over 13, and the fixed carbon from about 40 to 60 per cent. The amount of ash in the coal as shipped is commonly large, ranging from 2 to 14 per cent in the product of the same mine, and even reaching 18 per cent in marketable coal.

In the southern Puget Sound field the coals of the several districts possess more or less distinctive characters, which in turn are connected with the geologic structure of the different districts. In the Newcastle-Issaquah and Renton-Cedar River districts, where there is a general freedom from faults and the folds are open, the coal is a hard lignite, high in its content of moisture. Farther south, in the Green River district, the coal is a friable bituminous coal, so much softer than the lignite as to reach the market with few large lumps and two-thirds of the coal very fine. The structure in this district consists of somewhat closer folds than those to the north, with small faults. In the Wilkeson-Carbonado district, with its more complex structure of sharp folds and overthrust faults, the coal is a coking bituminous coal, low in moisture and high in fixed carbon. This coal is very soft and crushed, so that the mined product is in the form of very small lumps with a large amount of slack. Most of the coal mined in this district requires washing.

In the eastern field the coal is also a coking bituminous coal, showing none of the crushed character of that from the Wilkeson or Carbonado mines. Thus the product of the Roslyn field as delivered in California is described as bright, clean, well-selected lump, with little fine coal. The 25-ton block of Roslyn coal exhibited at the Chicago World's Fair is further evidence that this seam has been little affected by mechanical disturbances. Careful sampling of the Roslyn seam in different portions of the Roslyn mine and of the "run of the mine" shows a remarkable uniformity in the quality of this coal.

The product of the northern field is a bituminous coking coal containing a large percentage of slack or fine coal. The coal of the southwestern field has not entered outside markets, and therefore its character is not known. Both lignite and bituminous coal are reported from this field.

The following table of coal analyses, taken from the reports of the Bureau of Equipment of the United States Navy Department for the years 1893–1898, affords a basis for a comparison of the Washington steam coals which have been furnished to naval vessels on the Pacific coast.

Chemical analyses of samples of coal, made at the navy-yard, Washington, D. C.

Coal.	Moisture at 110° C.	Volatile matter other than H_2O.	Fixed carbon.	Ash.	Sulphur.	Phosphorus.	Increase in weight at 250°F.
Wilkeson	0.700	23.545	56.895	18.715	0.145	0.009	....
Franklin	3.26	35.36	57.58	3.80	.097	....	1.61
Do	4.559	33.501	46.668	15.08	.192	....	....
Franklin (McKay)	1.300	39.254	56.400	2.884	.162	.007	....
Black Diamond	3.040	36.566	56.084	4.166	.144	.023	....
Newcastle, vein No. 4	13.59	32.31	48.32	5.78	.164	....	3.78
Newcastle	7.992	29.031	53.806	8.023	1.148	....	....
Gilman	10.240	32.640	51.321	5.714	.085	.004	....
Blue Canyon	1.790	31.479	62.744	3.679	.308	.006	....
Fairhaven	.310	22.265	62.395	14.885	.145	.245	....
Do	2.98	35.03	59.98	2.01	.202	....	.867
Roslyn	2.05	33.55	54.55	6.85	.106	....	.402
Do	2.718	34.275	50.109	12.753	.145	....	....
Do	1.450	32.794	53.656	11.944	.156	.008	....

In the above analyses the small amount of sulphur present in the Washington coals is worthy of note. The tests given in the last column of the table show the relative liability of these coals to spontaneous combustion, and the importance of this test is readily seen in view of the well-known dangerous character of the Newcastle and Franklin coals, while the Roslyn coal does not show any such tendency.

The coal from Burnett, Wilkeson, Carbonado, and Fairfax makes an excellent quality of coke, is a good gas coal, and is well suited for locomotive use. In comparative tests made on the U. S. S. *Mohican* the Wilkeson coal was found to ignite readily, but to cake, so that the fires require a strong draft and considerable working. The clinkers formed in very small amount and did not cling to the grate bars.

The Green River coal does not coke well, but is an excellent steam coal, being a free-burning coal, with very little soot and remarkably low percentage of ash, as shown in naval tests. This coal swells in burning, but does not cake or clinker badly. Where the coal is very fine there is some waste of fuel through the grate bars.

The lignites of Newcastle and Renton are high grade and well suited for domestic purposes. The former, as tested at the Mare Island Navy-Yard, was reported to ignite slowly and to burn with a moderate amount of smoke and clinker. Coal from Newcastle No. 4, tested on the U. S. S. *Alert* and *Bennington*, was reported as unsuited for naval purposes, the chief defect being the excessive quantities of soot formed, which ignites in uptakes and smoke pipes.

The coals of the northern Puget Sound field are coking coals, and the larger part of that mined at Cokedale is made into coke. Blue Canyon coal has been tested on the U. S. S. *Mohican* and found to be a good steaming coal, with a small amount of ash, free burning, and requiring very little working. At higher speeds its efficiency outranked that of other Washington coals. The amount of slack is large, however, and the percentage of volatile matter too high to make this a desirable coal for naval purposes.

The Roslyn coal is a coking bituminous coal, well adapted for steam raising and gas making. It is an excellent fuel for locomotives, and over one-half of the product of this eastern field is sold for railroad consumption. The clean character of this coal and its high percentage of lump make it well fitted for shipment. The naval tests have shown that the Roslyn ignites quickly, combustion being rapid and thorough and the coal swelling slightly on the surface of the fire. The percentage of ash is moderate, and the clinkers formed do not cling to the grate bars, except with forced draft. The amount of soot formed and the high temperature in the uptake are the objectionable features of this coal.

Boiler tests made at the Mare Island Navy-Yard in 1895 and 1897 afford a basis for a comparison of the steam-raising efficiency of several Washington coals with high-grade Eastern, Rocky Mountain, and foreign coals. The following table doubtless furnishes the most authoritative and exact data available for putting a just commercial value on the best of the steaming coals from this State:

Boiler tests of coals.

Source of coal.	Pounds of water evaporated by 1 pound of coal.
Franklin, Wash	6.78
Blue Canyon, Wash	6.597
Roslyn, Wash. (1895)	6.287
Roslyn, Wash. (1897)	6.243
Newcastle, Wash	5.965
Georges Creek, Md.	7.5
New South Wales	6.966
Castle Gate, Utah	6.934

DEVELOPMENT.

BRIEF HISTORY OF COAL MINING.

The first discovery of coal in the State was made in 1848, lignite of poor quality being then found in Cowlitz Valley. Four years later coal was discovered on Bellingham Bay in Whatcom County, and here the first mine was opened. Shipments from this mine began in 1860 and continued until 1878, when spontaneous combustion caused a fire which necessitated abandonment of the workings. After this the northern counties did not ship coal until in 1891, since which time two or more mines have been active.

In King County coal was reported as early as 1859, and in 1862 mining began near the location of the present Issaquah mines, and 350 tons of coal were taken to Seattle by teams and scows. At first this coal brought $22 per ton, but when the price dropped to $12 it was insufficient to pay for mining and transportation. The Newcastle mine was in reality the pioneer mine of importance in this field, and in 1867 coal began to come to Seattle from this source. The value of this field as a source of supply for California was recognized, and by 1870 the means of transportation from the mine to Seattle was well established, a tramway taking the coal down to Lake Washington, where barges were towed across to the western shore, then carried on a tramway to Lake Union, and thence towed to Seattle. The following year this coal began to be shipped to San Francisco, and in 1877 the King County coal became a very important factor in this market, as the northern shipments then first exceeded in amount the receipts from the Mount Diablo field. At this time the workings at Newcastle had become extensive and the Talbot and Renton mines had been opened and had begun to ship to California. The coal at Renton had been discovered in 1860, but the first work done there was in 1873. Rail connection between the Renton mines and Seattle was secured in 1877, and the line was extended to Newcastle the following year.

The Green River field was thoroughly prospected in 1880 and the years immediately following, and in the same period the Northern Pacific parties were also thoroughly investigating the coal resources of the Pierce County field. The Wilkeson occurrence of coal had been known several years before, and the railroad was built from Tacoma to tap the field. In 1875 a ton of coal from Puyallup Valley was taken to San Francisco and tested with good results, but the field was practically abandoned in 1880. In the years following, however, Pierce County began to take a prominent place as a source of coal.

Coal was discovered east of the Cascades early in the eighties, and the Roslyn mine was opened, soon becoming a large producer. In 1894 the coal was reached by the Clealum shaft, and several other smaller mines are now operated in this field.

METHODS OF MINING.

The mines of the Northwestern Improvement Company at Roslyn and Clealum constitute the largest colliery in the State. While this property has suffered from mismanagement in the past, the management for the last five years has been most efficient, and in that period the annual output of the mine has been more than trebled. There are at Roslyn one shaft, one slope, and two drifts, affording four separate hoisting and airway openings, all connected by underground workings. The shaft at Clealum has not been connected with the Roslyn shaft, 4 miles distant, and the intervening ground represents the reserve coal supply of these mines. A disastrous explosion occurred in this mine in 1892, but at the present time the extensive workings have excellent ventilation, so that there is no trouble from gas. The mine is also piped, so that frequent sprinkling prevents any danger from coal dust. The double-room and pillar system is used. The seam as worked measures over 4 feet in thickness, and the coal is shipped just as it leaves the breasts. The daily capacity of this colliery with present equipment is estimated as 5,000 tons, and the management is now working with the purpose of enlarging the plant to obtain the maximum output. The miners in this field are both white and colored, and the constant employment offered at this mine has attracted the better class of miners, many of whom own their homes.

The second largest mine in Washington is the Carbon Hill, operated by the Pacific Improvement Company of San Francisco. Conditions here are wholly different from those in the Roslyn Basin. The coal seams have steep dips and in most of the workings the coal above water level has been exhausted. Slopes and drifts are driven on the different seams mined, gangways extending nearly 2 miles into the mountain-side. Small locomotives are used for underground haulage. Many openings are driven upward to the surface to facilitate distribution of the timber, which comes from the immediate vicinity and is used in large quantities in the cogs, which are built as the coal is extracted. Gas is very troublesome in these mines, and in some workings only safety lamps are allowed. The mines are well ventilated. The present capacity of this mine is 1,200 tons a day, and all of the coal mined goes through the washers. At the mine of the Wilkeson Coal and Coke Company the gangways have been extended to a distance of over 2 miles, and the supply of coal above water level has not been exhausted. The present daily capacity is estimated at 500 tons. The coal is washed, and nearly one-half of the product goes to the coke ovens. The mine of the South Prairie Coal Company at Burnett, in the northern part of this same field, is worked by a slope. The management of this property has made an enviable record in its treatment of the miners, who have better accommodations than can be found in any other coal camp in the State. This efficient and humane administration of the superintendent has affected not only the welfare of the miners, but also the success of the company and even of the coal industry of the whole State.

The Black Diamond Company has the third largest colliery in the State, the property being worked from slopes by the breast-and-pillar system, the pillars being all extracted. The mine is well ventilated, and the freedom from accidents and fires in this mine is in marked contrast with the record of the Franklin mines, a few miles distant, and testifies to the fact that this company has continued the able management that characterized its operations in the Mount Diablo field of California. The Pacific Coast Company has been obliged to practically abandon its mines Nos. 1 and 2 at Franklin, but is operating three new mines in the same district. These mines are being developed with the purpose of largely increasing production. Slopes and gangways are being extended and new machinery is being installed. Attention is given to efficient ventilation of the workings. Negroes have been employed to a large extent at Franklin.

In the Newcastle district the Pacific Coast Company is also making important improvements. The coal seams at Coal Creek are opened by a double-track tunnel over a mile in length, equipped with electric lights and a system of electric haulage. Over 2 miles of gangways on water level make this mine an important producer.

In the northern field the steeply inclined coal seams are worked through shafts and tunnels. The large quantity of gas is a dangerous element in these mines.

No machine mining is done in the State, trials in the larger mines not proving successful.

PRODUCTION.

The production of the State by groups of counties or distant fields is given in the following table:

Annual production of coal in Washington by groups of counties.

[Short tons.]

Counties.	1887.	1888.	1889.	1890.	1891.	1892.	1893.
King and Pierce	569,746	823,491	689,397	803,378	700,831	872,761	985,805
Thurston	15,295	42,000	46,480	15,000	....	22,119	....
Skagit and Whatcom	....	....	....	....	7,400	33,459	25,605
Kittitas	104,782	220,000	294,701	445,311	348,018	285,088	253,467
Total	[a]772,601	[b]1,215,750	1,030,578	1,263,689	1,056,249	1,213,427	1,264,877

Counties.	1894.	1895.	1896.	1897.	1898.	1899.	1900.
King and Pierce	829,507	873,000	901,278	1,041,882	1,294,948	1,353,688	1,562,948
Cowlitz and Lewis	26,880	168	1,263	1,248	1,848	780	800
Skagit and Whatcom	17,453	36,708	27,010	20,325	21,379	14,203	10,130
Kittitas	232,580	281,534	265,953	370,657	566,396	661,210	873,751
Total	[c]1,106,470	1,191,410	1,195,504	1,434,112	1,884,571	2,029,881	2,447,629

[a] Includes 82,778 tons not specified.
[b] Includes 130,259 tons not specified.
[c] Includes 50 tons mined in Okanogon County.

Since 1894 the output of the State has shown a steady increase, and in 1900 a single county, King, reached the million-ton mark. The principal companies in the order of their output are the Northwestern Improvement Company of Roslyn, the Pacific Coast Company (operating five mines in two districts), the Pacific Improvement Company (Carbon Hill Company), the Black Diamond Company, the Wilkeson Coal and Coke Company, the Issaquah Coal Company, and the South Prairie Coal Company, each of which produced over 100,000 tons in 1900, and the first named over 1,000,000 tons in 1901.

PROSPECTIVE DEVELOPMENT.

As has been already stated, the prospect is good for a steady development of the coal industry of Washington. The two largest companies are making material additions to their plants that warrant the promise of a marked increase in production, this being especially noticeable in the decision of the Northwestern Improvement Company to enter the Carbonado district and develop a large mine on the Upper Carbon River. This increase in production is plainly to be attributed to the industrial activity of the Pacific States and the enterprise of the larger companies in enlarging the market for Washington coal, the Roslyn coal having found a market in Honolulu. Under present conditions, commercial and industrial, the continued prosperity of the coal industry of the State seems assured.

DISTRIBUTION.

MARKETS.

It may be stated that practically the whole area of the three Pacific States is supplied with Washington coal. San Francisco furnishes the largest market, while the railroads of the northwest consume large quantities of the steam coals of this State. The railroads of California are to a small extent supplied with local coal, and oil is being used on the southern lines, but that Washington is an important source of locomotive coal for California roads is shown by the fact that practically the total output of the second largest colliery of Washington is shipped to San Francisco for the use of the Southern Pacific. Wood is used by the locomotives of some of the Oregon lines. The northern transcontinental lines use Washington coals largely. The Oregon Railway and Navigation Company uses Washington coal as far east as Huntington, Oreg., while the Northern Pacific, tapping the Roslyn field east of the Cascades, finds it economical to use this coal as far east as Helena, Mont. On the other hand, the Great Northern Railway, not being so favorably located with reference to the coal fields, does not use Washington coal east of the summit of the Cascade Mountains.

The local markets of Washington and adjoining States constitute the third important demand for Washington coal. The manufactories and the gas works in the larger cities depend largely upon coal for fuel. In Spokane fully 80 per cent of the coal supply comes from the Roslyn mines, while the remainder comes from Montana and Wyoming, with a few carloads from British Columbia, and 8 or 10 carloads of Pennsylvania anthracite, which is shipped via the Great Lakes and Duluth. The case of Spokane's supply is cited as illustrative of the region where the Washington coal competes with that from the Rocky Mountain collieries.

The coke manufactured in Washington is of high grade and is consumed by smelters at Tacoma, Everett, and Northport, and in California.

CONSUMPTION.

The following table shows the disposition of the coal output of Washington for the year 1900, not including coal used for steam purposes at the mines.

Disposition of coal output of Washington in 1900.

	Tons of 2,000 lbs.
Consumed by railroads in Washington, Idaho, Oregon, and Montana	611,728
Exported to California	783,481
Exported to Hawaiian Islands	70,894
Exported to Alaska	13,436
Consumed by steamers in foreign trade (plying between Puget Sound ports and the Orient)	43,452

	Tons of 2,000 lbs.
Consumed by steamers in domestic trade	218, 114
Consumed by United States vessels (naval vessels, revenue cutters, and Army transports)	42, 715
Manufactured into coke	57, 010
Consumed in Washington, Idaho, and Oregon for domestic and steam purposes	577, 204
Total output	2, 418, 034

TRANSPORTATION ROUTES AND CHARGES.

In the northern field the Cokedale coal reaches the Puget Sound ports via the Great Northern Railway. The coal from the Blue Canyon mine is transferred across Lake Whatcom on barges and thence by rail to Whatcom.

The coal of the southwestern field is all consumed locally, but if this field is developed so as to have a larger production, it is favorably situated to supply Portland.

The eastern or Roslyn field, being east of the crest of the Cascades and on the line of the Northern Pacific Railway, naturally commands the coal trade of eastern Washington, Idaho, and eastern Oregon. The charges to Spokane, which is near the eastern limit of the area supplied with this coal, are $2.85 per ton. The quality of the Roslyn coal has enabled it to compete also with the Puget Sound coals in the export trade. Rates to San Francisco and Honolulu from this field are reported as $2.75 and $4.50, respectively.

The coals from the different districts of the southern Puget Sound field reach Puget Sound ports by short hauls over branches of the Northern Pacific and the Columbia and Puget Sound Railroad, which taps the Green River, Renton, Cedar River, and Newcastle mines. The charges from these mines to Tacoma and Seattle vary from 40 to 80 cents per ton. The rates to San Francisco by steam colliers are reported as ranging from $1.25 to $2.50 per ton, while the rail rate to Portland is $1.75.

The coal-carrying roads of the State are interested in the present development of the coal industry, the Northern Pacific being intimately connected with the largest coal-mining company, and the Columbia and Puget Sound Railroad, now a standard-gauge road, being controlled and operated by the Pacific Coast Company. Several lines are proposed to connect new properties with the Northern Pacific lines. It is evident that the transportation facilities will be improved to keep pace with the prospective development of the coal mines of the State.

CALIFORNIA.

GEOGRAPHIC RELATIONS.

The coal product of California comes from four counties—Alameda, Contra Costa, Amador, and Riverside. The coal fields are limited in extent and are usually so situated as to necessitate separate description. At the present time there are four productive coal fields in the State. The Mount Diablo field deserves first mention, as the oldest, although not the most productive at the present time. It is situated in Contra Costa County, about 35 miles north of east of San Francisco, on the northern slope of Mount Diablo, which is an isolated peak of the Coast Range system. The coal formation in this area covers a belt not over 2½ miles in length, curvilinear in outline and convex northward. Somersville is the principal town within the area.

The second field is the Corral Hollow, which includes an area on both sides of the divide between Livermore Valley and San Joaquin Valley, and is for the most part in Alameda County. It lies 50 miles southeast of San Francisco and on the southeastern slope of Mount Diablo, so that it may be considered as a continuation of the first-mentioned field.

The Ione coal field, in Amador County, is situated in the foothills of the Sierra Nevada, 90 miles northeast of San Francisco. This field has a probable extent of about 4 square miles.

The fourth field is situated in the southern part of the State, in Riverside County, near Elsinore. It lies at the eastern foot of the Sierra de Santa Ana. The probable extent of the coal formation in this field is not great.

Extensions of these coal fields appear for the most part extremely doubtful. The Ione field may have an extension to the south to Lancha Plana, where coal has been mined to some extent. In many other counties coal veins have been prospected to a greater or less degree, and Butte, Del Norte, Orange, Fresno, Monterey, San Diego, and other counties have been on the productive list in years past. However, mines that once were operated in these counties are now abandoned, owing to exhaustion of the coal, difficulty in mining, or change in quality of the coal itself. Coal prospects more or less promising are reported from Fresno, Trinity, Mendocino, Placer, and Orange counties. The quality of these coals, as well as the cost of transportation, will prevent these areas from ever becoming factors in the San Francisco market. In some cases, however, the coal beds may prove of value as a local supply of fuel. As will be shown in a following section, it seems certain that California will never take much higher rank as a coal-producing State than it possesses at the present day.

GEOLOGIC RELATIONS.

AGE OF COAL-BEARING ROCKS.

The older geologic formations in California are practically barren of coal. The Carboniferous rocks never include coal beds, while the Cretaceous coal deposits have never proved of economic importance. The coal deposits are thus entirely of Tertiary age. The earlier Tertiary or Eocene (Tejon) has furnished the greater part of the coal mined in this State. The Mount Diablo and Corral Hollow fields are in rocks of Eocene age. The later Tertiary or Miocene formations furnish the largest areas of coal-bearing rocks, although the quality of the coal in these younger rocks is somewhat inferior. The Ione field and the Elsinore field have coal beds of Miocene age.

STRATIGRAPHY AND STRUCTURE.

The general subsidence of the region of the Coast Ranges in Tertiary time was followed by local deposition of coal and associated sediments. Later folding, faulting, and erosion have caused these areas of coal-bearing rocks to be even more limited in extent. On this account the careful investigation of the geologic relations becomes even more important here than in fields where the coal measures are regular and widely distributed. An understanding of these relations is also necessary in forming an accurate estimate of the coal resources of the State.

In the Mount Diablo and Corral Hollow fields the Tejon formation consists of light-colored sandstones and associated shales and probably measures about 1,000 feet in thickness. In the former fields the rocks have a general east-west strike, with dips of 12° to 33° N., or away from the Mount Diablo mass. The coal beds and associated strata are subject to great variations, both in character and in thickness. The formation is greatly disturbed, small faults being numerous. In Corral Hollow the rocks are much the same as on the north side of Mount Diablo, but here the faulting is more extensive and the dips of the coal beds are much higher, being from 30° to 80°.

The Eocene rocks of the Ione field comprise sands and clays measuring about 1,000 feet. Three coal beds occur in the upper part of this formation, or about 800 feet from its base. The structure of the field is simple, being a shallow basin with low dips. Limonite ore also occurs in this formation.

In the vicinity of Elsinore, in Riverside County, the Miocene rocks occur in a small basin surrounded by crystalline rocks. The formation comprises sandstone and sandy shale, with the coal bed near the base of the formation, granite being found only 40 feet below the floor or foot wall. The structure here is simple and the dips are low, being from 3° to 10°.

THE COAL.

NUMBER AND EXTENT OF WORKABLE BEDS.

The coal beds of the Mount Diablo field are three in number. The uppermost is the Clark, the next the Little, and the lowest the Black Diamond. The section of that part of the Eocene rocks in which the coal beds occur is quite variable, so that the stratigraphic distance between the Clark and the Black Diamond seams varies from 300 to 400 feet in different parts of the field. The Clark seam has been a favorite in the different mines, and has been worked continuously throughout the field. It has a thickness of from 2 to 4 feet of coal, which is generally free from slate, and the seam for the most part possesses a good floor and roof. As is the case with all the coal seams of California, the outcrop is generally a light, soft shale, not at all resembling coal, and marketable coal is not found in the seam until a depth of at least 100 feet is reached. The Little seam is more irregular in thickness, but where worked has about 2 feet of good clean coal. The character of the roof and foot wall, however, makes this coal more expensive to mine than that in the Clark seam. This is also true of the Black Diamond seam, which, while the thickest seam of the three, having from 3 to 4 feet of coal, has associated with it such amounts of slate and bone as to make the mining expensive and often dangerous on account of the swelling of the bone, which causes crushing of the mine timbers. The quality of this coal from the Black Diamond seam has been reported in later years as inferior to that of the upper seam, although in the earlier development of the field this coal was found to be rather hard, and therefore superior to the coal of the Clark seam.

In the Corral Hollow field there are a number of coal seams, but the productive ones at present are the Eureka and the Summit. The Eureka has been developed to a considerable extent and is 10 to 12 feet in thickness, of which only the upper bench of 6 to 8 feet is mined. The roof is of solid sandstone, but the floor is less satisfactory. The Summit seam averages 7 feet of clean coal and has an excellent floor of hard sandstone, but the roof is slate, which from its shaly character involves expense in timbering. These seams are believed to extend over a large area, and with the other coal fields may constitute an available supply for years.

The Ione coal comes from a thick seam, which is practically horizontal and extends under the whole of the valley between Ione and Carbondale, and probably also south. The depth below the surface of the coal is about 80 feet. The seam is 6 to 24 feet in thickness, of which 8 feet is mined at the present time. Both walls are of clay.

In the Elsinore field the coal seam is 3 to 10 feet in thickness, 6 feet of which is being worked. The roof is sandstone and the floor clay. The seam is 85 feet below the surface and has only low dips.

CHARACTER OF THE COAL.

The coals of California are lignites, soft and friable. That of the Ione field is of a dull brown color and distinctly shows the woody texture, while in the Mount Diablo mines carbonized wood and pyrite are found associated with the coal, and also gypsum above the water level. Analyses of California coals show 11 to 15 per cent water, 41 to 47 per cent volatile constituents, 30 to 38 per cent fixed carbon, and 6 to 12 per cent ash. The Tesla coal, as tested at the Union Iron Works in San Francisco, was found to be of uniform quality, burning freely, with an ash percentage of between 8 and 9 per cent, with comparatively few clinkers. The water evaporated in its commercial test was 6.557 pounds per pound of coal. The following analysis of the Corral Hollow lignite, by R. C. Hills, may be considered as typical for the best grade of California coal:

Analysis of Corral Hollow lignite.

Moisture at 100° C	10.80
Volatile combustibles	43.10
Fixed carbon	38.57
Ash	7.53
Total	100.00

These lignites burn freely and, although they have a large percentage of ash, do not clinker badly. The Eocene coals of Mount Diablo and Corral Hollow are of better quality than the younger coals of the Ione and Elsinore fields. The former coals crumble somewhat upon exposure, yet they can be shipped to San Francisco and other California cities. The Ione coal, on the contrary, while well suited for the local supply, can not be transported to any great distance. It is used, however, in Sacramento, where furnaces of special construction have been erected, since this coal needs plenty of air and frequent firing, and under these conditions it makes a satisfactory and cheap fuel. The Elsinore lignite has been found to be a good steam coal for stationary boilers, but is too light for locomotive use.

DEVELOPMENT.

HISTORY OF DEVELOPMENT OF THE FIELDS.

The Mount Diablo coal fields were early discovered, and in 1861 had already begun to ship coal. The product for that year is reported as 6,000 tons. The maximum production of this area was reached in 1874, when 206,000 tons were mined. A complete history of the field would record the existence, more or less varied, of many companies, but of these only two seem to have mined coal at a profit, namely, the Black Diamond and the Pittsburg companies, and only the latter is still working in this field. The thinness of the coal seams, the disturbed character of the rocks, and the poor quality of the coal have been factors which contributed to the failure of the companies. Shortsighted policy and poor management have made the mining of coal in this district unnecessarily expensive, and, as pointed out by W. A. Goodyear over twenty years ago, the productive portion of this field is not too large to have been operated by a single mine, and if this policy had been adopted nearly two millions of dollars could have been saved.

The Corral Hollow field was discovered and somewhat prospected in 1862. The Pacific or Eureka and the Almaden mines were the earliest ones to be opened. Little work was, however, done and the field was then abandoned. Good, natural exposures of the rocks in this field are rare, so that underground exploration is necessary, which proved too expensive for further development of the field at that time. The Commercial mine produced coal in 1869 and 1870, but in the latter year the works were burned down and the mine was on fire. The Livermore mine was abandoned after eighteen months' operation in 1875 and 1876. The present period of the development of this field began in 1897, since which time the output has steadily increased.

The Ione field was known as early as 1866, but did not become a factor in the coal trade of the State until 1877, when the production for the year was 3,500 tons. Little work was done, however, until 1883, when the daily output reached 40 to 60 tons. In 1888 two companies were mining coal in Ione and Buckeye valleys, with a daily production of from 70 to 100 tons. In the two years 1891 and 1892 the Sacramento and Ione Coal Company produced about 24,000 tons, while the Ione Coal and Iron Company at the same time were mining 100 tons a day. This output doubtless marks the maximum production of this coal field.

The coal in the vicinity of Elsinore, in the southern part of the State, has been mined for about fifteen years. The demand is only for local consumption, and mining operations in this field have always been on a small scale.

MINING METHODS.

In the Mount Diablo and Corral Hollow fields the dips of the coal and associated beds are high, and slopes, shafts, and tunnels have been used to reach the coal seams. The Pittsburg mine in the former field is at present operated by a shaft and slope, with gangways driven from two levels. The coal is mined by the breast-and-pillar method, and the whole product is shipped as it leaves the breasts. There is no trouble with gas in this mine. The present workings are 600 and 750 feet below the surface. The Tesla mine in Corral Hollow is opened by both a tunnel and a shaft, and the breast-and-pillar system is used. Electric haulage and lighting systems have been installed in this mine, and the whole equipment is up to date. The coal from the Eureka seam is screened and washed, but that from the Summit seam is sufficiently clean to go direct to the bunkers.

In the Ione field, mine No. 4 of the Ione Coal and Iron Company has a shaft 80 feet deep. The seam being horizontal, the coal is easily mined. In the Alberhill mine, in Riverside County, a tunnel reaches the coal seam, and here also the low dip of the rocks favors the extraction of the coal at a minimum of expense.

The coal of all the California fields is so soft that no machines are used. There are no coal miners' unions in the State.

PRODUCTION.

The first table in this report (p. 479) shows the annual coal product of California since 1883. The statistics for the production in earlier years are less accurate. They show, however, that from 1867 to 1882 the annual output of the California mines only once dropped below the 100,000-ton mark, while in 1872, 1873, and 1874 the annual production exceeded that of last year. The present outlook is encouraging, in that production has steadily increased for the last five years.

The following tables show the production for the last two years:

Coal product of California in 1899, by counties.

County.	Number of mines.	Loaded at mines for shipment.	Sold to local trade and used by employees.	Used at mines for steam and heat.	Total product.	Total value.	Average price per ton.	Average number of days active.	Average number of employees.
		Short tons.	*Short tons.*	*Short tons.*	*Short tons.*				
Alameda, Amador, and Contra Costa	3	147,641	137	4,432	152,210	$406,771	$2.67	292	345
Kern, Orange, and Riverside	3	3,400	5,105	....	8,505	21,562	2.54	272	18
Total	6	151,041	5,242	4,432	160,715	428,333	2.67	291	363

Coal product of California in 1900, by counties.

County.	Loaded at mines for shipment.	Sold to local trade and used by employees.	Used at mines for steam and heat.	Total product.	Total value.	Average price per ton.	Average number of days active.	Average number of employees.
	Short tons.	*Short tons.*	*Short tons.*	*Short tons.*				
Alameda, Amador, and Contra Costa	158,508	50	6,650	165,208	$505,981	$3.06	312	360
Orange and Riverside	2,000	4,500	....	6,500	17,250	2.65	245	18
Total	160,508	4,550	6,650	171,708	523,231	3.05	309	378

The two companies occupying the Corral Hollow and Mount Diablo fields are engaged in extending their development work, which will result in a steadily increasing output. There is little probability, however, of new mines being opened in these fields, which from their situation are the only ones that can be expected to directly affect the San Francisco supply.

DISTRIBUTION.

MARKETS.

The consumption of California coal is chiefly local and is in great part confined to towns immediately adjacent to the coal fields. This is particularly true of the southern California fields, where all the coal is used by local consumers. So, also, the Ione product can be shipped only to interior towns where there is no water competition. The Pittsburg and Tesla mines therefore constitute the domestic supply for the largest cities of California, where this coal competes with that from outside the State.

CONSUMPTION.

The railroads consume about 20 per cent of the coal product of California, and the bay and river steamboats approximately the same proportion. Flour mills and other large manufacturing establishments in San Francisco, Sacramento, Stockton, and other large cities take 35 per cent, while the remaining 25 per cent is consumed at the mines and for domestic purposes in the colliery towns. No coal is exported from the State, since it is only by reason of proximity to the San Francisco market that the California lignites can compete even there with the better quality of coals from outside the State. The sources of the coal in the San Francisco market will be treated in a later section of this report.

TRANSPORTATION ROUTES.

As noted above, the Ione coal supplies only interior towns, and the Southern Pacific Railroad is the route by which this coal reaches its markets. The Pittsburg mine ships by its own railroad to the bunkers of the Southern Pacific and Santa Fe railroads, and can also deliver to the steamers and vessels on San Joaquin River. The Tesla mine of the San Francisco and San Joaquin Coal Company ships its coal product over the company's standard-gauge railroad, the Alameda and San Joaquin Railroad, to Stockton, whence it can be shipped by water to San Francisco. At both of these larger mines coal can be mined and delivered at tidewater at rates favorable to the operators. The freight charges for the Tesla coal to Stockton are 25 cents per ton, while the rate to the seaport of San Francisco is 65 cents. Under present conditions the demand and transportation facilities are sufficient to insure the immediate shipment of all coal produced in the Corral Hollow and Mount Diablo fields.

OREGON.

GEOGRAPHIC RELATIONS.

The State of Oregon has but one productive coal field. This is the Coos Bay field, in Coos County, on the coast, somewhat more than 200 miles south of the mouth of the Columbia, and among the foothills between the Coast Range and the Pacific. Its length north and south is about 30 miles, its maximum breadth 11 miles. The total area is about 250 square miles. Since this is the only field in the State which has ever been productive, the principal portion of this report will deal with it. Other coal fields which have been more or less prospected and shown to contain coal of good quality may be mentioned here. These are the Upper Nehalem field, in Columbia County; the Lower Nehalem field, in Clatsop and Tillamook counties; the Yaquina field, in Lincoln County, and the Eckley and Shasta Costa fields, in Curry County. All of these fields lie west of the Cascade Range. East of the Cascade Range coal has been found in the basin of the John Day River, but little is known concerning this field.

Explorations of the coal fields of western Oregon are necessarily slow. The luxuriance of the undergrowth and the abundance of fallen timber, together with the few and meager exposures of the rocks, are great difficulties attending the investigation of the geology and resources of the region. The Upper Nehalem field has an area of less than 20 square miles. Two beds of coal are reported, but at present there are no facilities for cheap transportation. The Lower Nehalem field has a smaller area, and the thickness of the coal seams is much less, although the quality of the coal is good. The Yaquina field is also limited in extent and contains several beds of coal, but the character of these beds is not such as to give promise of any commercial importance.

GEOLOGIC RELATIONS.

STRATIGRAPHY.

It may be stated that all the coal deposits of Oregon are of Tertiary age. Where there has been positive determination by means of fossils the coal formations are known to be of Eocene age, and it is probable that in the other fields the age is the same. In the Coos Bay field the coal-bearing strata have been termed the Coaledo formation. One of the interesting characters of this formation is the occurrence of fresh or brackish water fossils in immediate connection with the coal, while between the coal beds and comparatively close to them fossils of purely marine origin are occasionally found. The Coaledo formation includes, besides the coal, sandstones and shales of considerable variety. In the lower portion of the formation sandstones predominate; then come the workable coal beds, with associated sandstones and dark-colored shales, while in the upper portion light-colored shales are most abundant. The accompanying figure (fig. 47) shows the stratigraphic section exposed in sec. 9, T. 27 S., R. 13 W. The strata have a total thickness of 608 feet, and contain six beds of coal, as well as beds of carbonaceous shale that show traces of coal.

STRUCTURE.

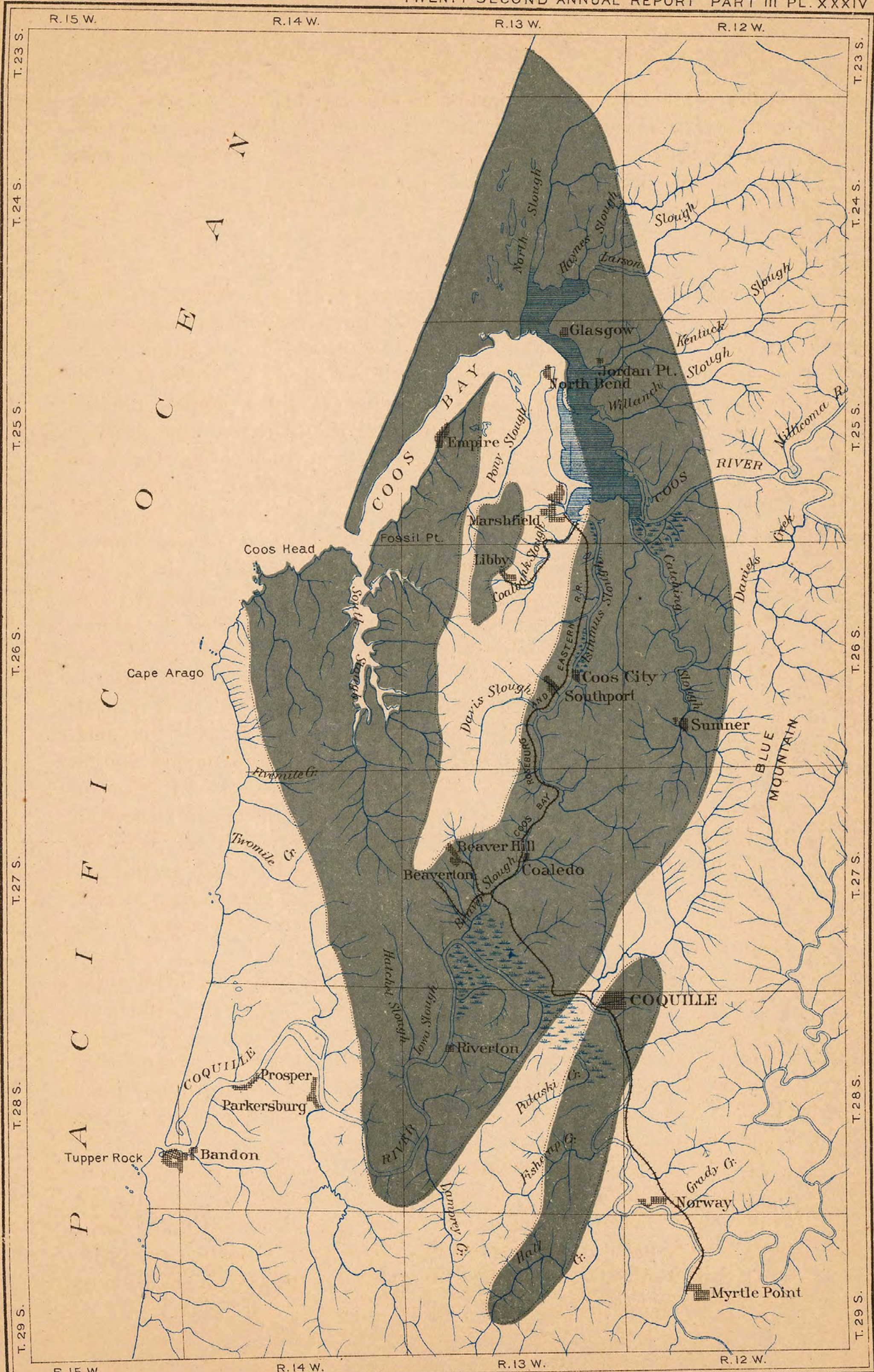
On the basis of the structure of the coal-bearing formation the Coos Bay coal field may be divided into six portions, four basins and two arches. The basins contain the coal, while the arches bring to the surface the strata which underlie most if not all of the coal beds. The basins are the Newport, the Beaver Slough, the Coquille, and the South Slough. These are separated by the Westport and Pulaski arches. The dark color used to represent the Coaledo formation on the map (Pl. XXXIV) indicates the extent of these coal basins.

The Newport Basin is named from its principal mine, the Newport, at Libby. The north-and-south length of this basin is about 3 miles, its average breadth about 1 mile. The coal lands include the greater part of secs. 4 and 9, T. 26, and sec. 33, T. 25, as well as small portions of adjoining sections, making a total area of nearly 3 square miles. Newport Basin is the smallest and narrowest basin of the whole coal field, and at the same time it is the highest relative to tide water, a structural feature of importance, inasmuch as it enables mining to be carried on more economically here than in other portions of the field.

The Beaver Slough Basin takes its name from its principal slough, which lies near the middle of the most important part of this basin. The length of this basin is over 20 miles, from the neighborhood of Riverton to the northern limit of Coos Bay. Its widest part is on the Coquille, where it is about 5 miles across. In its central portion the basin is deep and contains a greater thickness of the Coaledo formation than can be found anywhere else in the basin. The depth of this basin is probably less than 2,000 feet.

The South Slough Basin has South Slough for its central topographic feature and is separated by the Westport arch from the Newport and Beaver Slough basins, which lie to the east. The South Slough drainage approximately outlines this basin. The remaining basin is the Coquille, which is outlined on the accompanying plate (Pl. XXXIV). The length of this basin is about 8 miles, its width nearly 1 mile.

The structure of these basins of the Coos Bay coal field may be considered as simple, the dips being rather gentle and large faults not common. Where faults have been found, as at Beaver Hill and Newport, their association with the ravines or sloughs is such as to apparently indicate that the presence of faults determines the location of the ravines.



MAP OF THE COOS BAY COAL FIELD, OREGON

Showing Coaledo formation, including productive coal beds

GEOLOGY BY J. S. DILLER

Scale

5 0 5 MILES

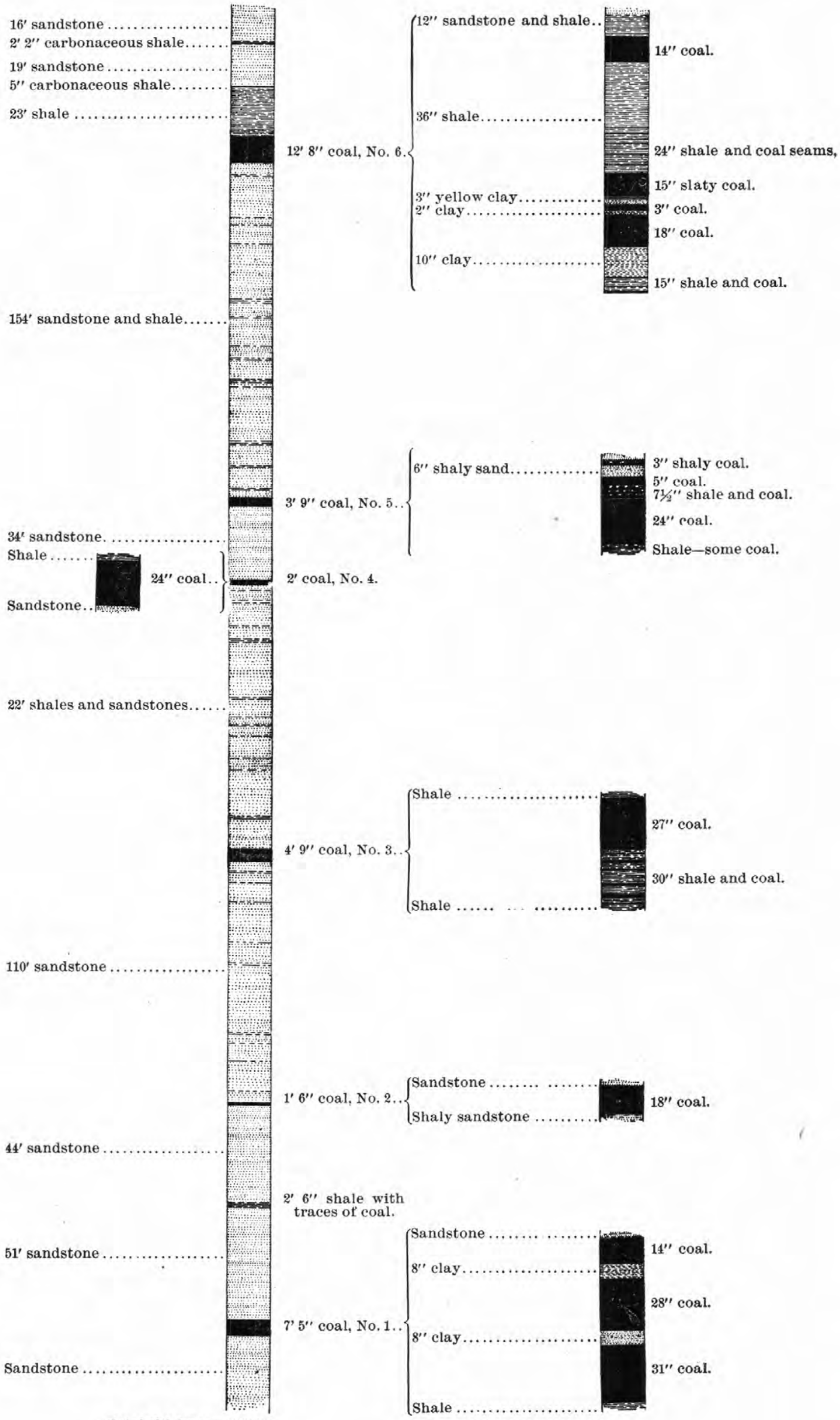


FIG. 47.—Sections of coals and associated rocks, Coos Bay, Oregon.

THE COAL.

IMPORTANT BEDS.

In the Newport Basin there is only one bed of coal that has been extensively worked. This is known throughout the region as the Newport. It contains about 6 feet of coal in three benches, yielding 5 feet that can be mined. This basin originally contained over 6 million tons of coal, a large part of which was available. Fig. 48 shows a section of the Newport bed in the Newport mine. The roof is generally sandstone, requiring comparatively little timbering. The top bench of coal is usually left up with the upper parting, to form the roof. This occasionally contains small veins of pitch coal or asphalt. The middle bench has within a few inches of its top a red streak that is very characteristic of the Newport bed. The bottom bench contains the best coal, although there is a small amount of bone at the base. This triple arrangement of the benches extends throughout the Newport Basin and is used in other parts of the field to identify the Newport bed.

In the Beaver Slough Basin five beds of coal have been found, the most important of which is the one at the bottom, which has over 6 feet of coal in three benches with two small partings (fig. 49). The similarity in character, position, and general structural relations of this coal bed and the Newport bed is such as to make it evident that they are the same. This is the bed which is mined at Beaver Hill and Beaverton, where it is locally known as the Beaver Hill coal. The overlying coals are sometimes referred to by number with respect to the Beaver Hill. Near Riverton the four principal beds of coal have been designated, beginning next to the bottom, the Urquhart, Bunker, Timon, and Kight. There are some indications that the Urquhart bed should be correlated with the Beaver Hill and the Newport.

Figs. 50 to 52 give sections of these coal beds where they have been mined. On the western side of Beaver Slough Basin, at Southport, coal has been mined, and the bed is generally known as the Southport.

Its relation to the beds already mentioned, however, is a matter of conjecture. Although this Southport bed is found only a few miles from Newport, the bed is not found within the Newport Basin, and its absence is explained by the supposition that it overlies the Newport bed by more than 100 feet and has, therefore, been eroded. Fig. 53 gives a section of the Southport coal.

In South Slough Basin several coal beds have been prospected, the largest of which is generally known as the Sevenmile or Big Coal shown in fig. 54. The amount of coal in this bed is variable and the coal is generally poor but soft, and containing a number of clay partings. The roof and floor are poor and such as to render mining difficult. At first this coal was regarded as the probable equivalent of the Newport coal. Later investigations tend, however, to show that it

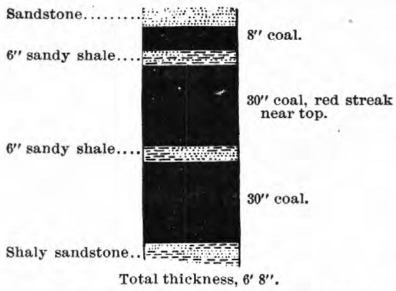


FIG. 48.—Section of Newport coal bed at Newport mine.

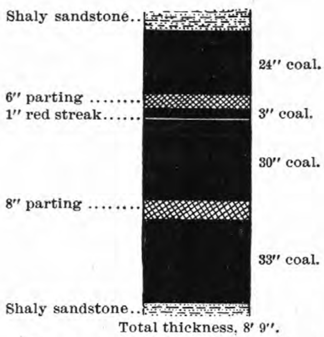


FIG. 49.—Section of Beaver Hill coal at end of No. 4 gangway.

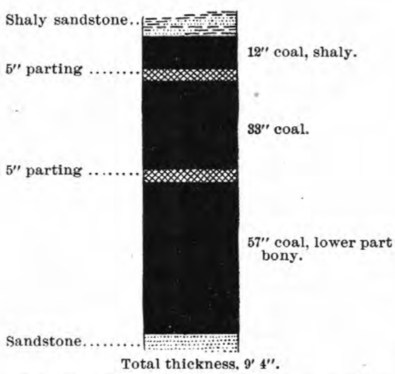


FIG. 50.—Section of Urquhart coal, Riverton.

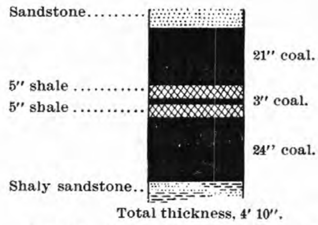


FIG. 51.—Section of Timon coal in Timon's mine, Riverton.

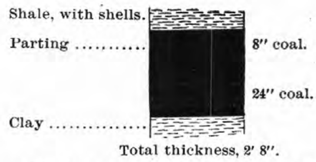


FIG. 52.—Section of Kight coal in Ferrey's mine, Riverton.

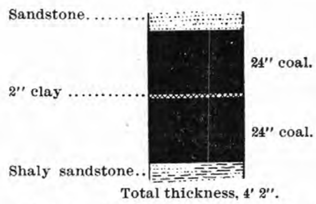


FIG. 53.—Section of coal at Southport mine.

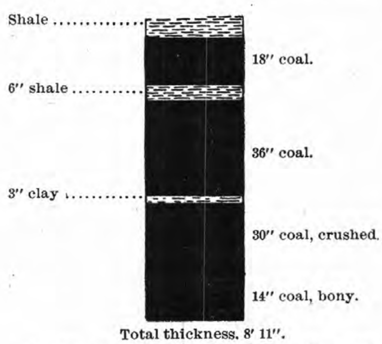


FIG. 54.—Section of coal on Sevenmile Creek, in eastern part of sec. 26, T. 27, S., R. 14 W.

lies far below that bed, and search has been made for it under the Westport arch. At present the indications are that the original extent of the bed eastward was limited, so that it may not be found to underlie the Newport Basin or even the Westport arch.

The coals of Coquille Basin are best exposed along the river south of Coquille, at Harlocker Hill. Three fairly thick beds of coal have been prospected here, but no mines have been opened.

CHARACTER OF THE COAL.

The coal from the Coos Bay mines is a lignite of a quality that prevents its competing as a steam coal with the other coals of the Pacific coast. For domestic purposes it is preferred to other coals, since it burns without smoke or soot. These Coos Bay lignites do not generally coke, although a sample of Norton's coal from Catchings Slough has yielded good coke in a laboratory test.

The following analyses may be considered as representative of the principal coals mined and prospected in the State:

Analyses of Coos Bay coals.

No.	Moisture at 105° C. 1 hour.	Rapid heating.		Ash.	Sulphur.	Physical properties of coke.	Analyst.
		Volatile matter.	Fixed carbon.				
1	17.27	44.15	32.40	6.18	1.37	Will not coke	Thomas Price.
2	9.56	49.85	35.98	4.61	0.94	Does not coke	George Steiger.
3	7.94	41.91	46.95	3.20	0.28	Will not coke	Do.
4	6.88	48.69	32.05	12.38	1.50	.....do	Do.

1. Newport coal, lower bench, Newport mine.
2. Beaver Hill coal, middle bench, Beaver Hill mine.
3. Southport coal, 5 miles south of Marshfield.
4. Sevenmile or Big coal, Parker's opening, sec. 26, T. 27 S., R. 14 W.

DEVELOPMENT.

HISTORICAL NOTES.

In 1855 Prof. J. S. Newberry reported that coal deposits on the shores of Coos Bay had begun to attract the attention of the public, and it was believed that at last bituminous coal had been found on the Pacific equal to that imported from the East. Professor Newberry saw several cargoes of coal from this field at San Francisco and Portland. Since that time Coos Bay has been a productive field. In 1872 there was considerable activity in this coal field, but in 1876 the Eastport and Newport mines were the only ones that were successful in their operations in this field, and of these two the Newport mine only has survived. It is interesting to note that in 1876 the foreman of the Newport mine estimated that the amount of available coal remaining above the gangway would not exceed two years' supply, and that only by driving another gangway could several years' further supply be furnished. Since that date, however, the Newport mine has produced many hundred thousand tons of coal.

METHODS OF MINING.

The Newport Basin is the most conveniently situated, with reference both to coal shipment and to coal mining. Three mines have been worked in this basin, but only one, the Newport, is in operation at present. This is operated by the Oregon Coal and Navigation Company, of San Francisco. The opening of the mine is a tunnel from Boatman Gulch, and is so planned as to tap the lowest point of the coal basin at about 100 feet above sea level. Slopes and counter drifts run in both directions from this main entry, and the coal is mined by the room-and-pillar method. A locomotive is used for the underground haulage. From the mine the cars are taken down a gentle grade to the bunkers on the bay.

In the Beaver Slough Basin, although the coal area is much greater, the production has not been so great as in the Newport Basin. The depth of the basin is not favorable to economic mining, and while many mines have been started in this basin—the Beaverton, Timon, Glasgow, Southport, Henryville, aud Utter—most of them have proved unsuccessful. The Beaver Hill mine of the Beaver Hill Coal Company of Marshfield, Oreg., is the only mine at all active, and even here no shipments are being made at present. Considerable development work, however, is being done in this mine, and the prospects are good for enlargement. The mine is on a branch of the Beaver Slough and is operated by a slope with gangways, from which the rooms are turned by the pillar-and-chute system. In other portions of the Coos Bay field, though there is considerable activity in the line of prospecting the many outcrops of coal beds, and though in some cases underground development has been pushed, yet the Newport mine is the only one in the district, and in fact in the State, to report regular shipments.

PRODUCTION.

In addition to the statistics of the first table in this report (p. 479), the following table will show the coal production of the State since 1892:

Coal product in Oregon since 1892.

Year.	Loaded at mines for shipment.	Sold to local trade and used by employees.	Used at mines for steam and heat.	Total product.	Total value.	Average number of employees.	Average number of days worked.
	Short tons.	*Short tons.*	*Short tons.*	*Short tons.*			
1892	31,760	2,353	548	34,661	$148,546	90	120
1893	37,835	3,594	254	41,683	164,500	110	192
1894	45,068	2,171	282	47,521	183,914	88	243
1895	68,108	5,294	283	73,685	247,901	414	[a] 69
1896	88,116	12,951	654	101,721	294,564	254	191
1897	92,921	5,207	9,161	107,289	291,772	375	200
1898	54,305	3,290	589	58,184	212,184	142	199
1899	78,608	6,656	1,624	86,888	260,917	124	238
1900	48,160	9,590	1,114	58,864	220,001	141	273

[a] The apparently large number of men employed and small average working time are due to the large force of men employed in developing the Beaver Hill mine, which was producing coal for shipment during only twenty days in 1895. The average time made at the Newport mine was over two hundred days per man.

Further development of the coal industry of the State depends largely upon the success of the development work in the Beaver Hill mine, which has not shipped coal since 1897. Development work is also being actively pushed at other localities in this field.

DISTRIBUTION.

MARKETS.

Outside of the small local demand, the market for the Coos Bay coal is San Francisco. At Portland the Washington and foreign coals control the market. The coal for shipment to California from the Newport mine is carried 4 miles, over a narrow-gauge railroad owned by the company, to tide-water bunkers, and thence by the company's steamers to San Francisco. The transportation rate is $2 per ton. Since the Coos Bay coal sells in this market for $1 less than the Washington coal, it will be seen that the former can maintain its place in the market only on a narrow margin of profit to the producer.

It is estimated that of the last year's output 10 per cent was sold to steamboats for fuel, 10 per cent to manufacturing establishments, and 80 per cent to the household trade. This disposition of the Coos Bay coal is doubtless a fairly accurate index of its qualifications as a fuel.

LITERATURE.

The following reports and articles constitute the available literature bearing on the subject discussed in the preceding pages:

GOODYEAR (W. A.). The coal mines of the western coast of the United States, San Francisco, 1877.

A very complete account of the early development of coal mining in the Pacific States.

WASHINGTON.

WILLIS (BAILEY). Some coal fields of Puget Sound: Eighteenth Ann. Rept. U. S. Geol. Survey, Part III, 1898.

This report has been used freely in the preparation of the section on the "Geologic relations" of the Washington field.

WILLIS (B.) and SMITH (G. O.). Tacoma folio of the Geologic Atlas of the United States, 1899.

STATE INSPECTOR OF COAL MINES. Reports.

MINES AND MINERALS. Coal mining in Washington, and Coal mines of Washington: Mines and Minerals, December, 1898, and January, 1899.

Descriptive of the Roslyn and Carbonado-Wilkeson districts.

CALIFORNIA.

TURNER (H. W.). The coal deposits of California: Mineral Resources U. S., 1892, pp. 308-310.

FAIRBANKS (H. W.). The coal beds of California: Eng. and Min. Journal, Vol. LXII, 1896, p. 10.

HORSEWILL (T. J.). The Tesla coal mines: Mines and Minerals, Vol. XIX, 1898, pp. 145-147.

STATE MINING BUREAU. Reports.

OREGON.

DILLER (J. S.). A geological reconnaissance in northwestern Oregon: Seventeenth Ann. Rept. U. S. Geol. Survey, Part I, 1896.

DILLER (J. S.). The Coos Bay field, Oregon: Nineteenth Ann. Rept. U. S. Geol. Survey, Part III, 1899.

These two reports have been used to a large extent in the preparation of the present report, and Pl. V has been adapted from the maps of the Coos Bay folio by Mr. Diller.

THE COAL RESOURCES OF ALASKA

BY

ALFRED HULSE BROOKS

CONTENTS.

ILLUSTRATION.

THE COAL RESOURCES OF ALASKA.

By Alfred H. Brooks.

INTRODUCTION.

Alaska embraces nearly 600,000 square miles and stretches through almost 20° of latitude and 50° of longitude. Practically no detailed investigations of any part of this vast Territory have been made, and of at least a third of its area not even preliminary topographic and geologic surveys have been made. Our knowledge of its mineral resources is therefore very incomplete, and this is especially true regarding the coal, which naturally has received relatively much less attention at the hands of prospectors than the precious metals. A few coal mines have been opened, and concerning these some detailed facts are obtainable. Elsewhere in the Territory occurrences of coal are only very briefly described or are only incidentally mentioned in the various reports dealing with the mineral resources.

In 1895 Dr. William H. Dall, of the United States Geological Survey, studied the coal resources of the Pacific coastal belt. His route extended from the neighborhood of Sitka to Unalaska on the Aleutian Islands, and he visited a number of localities in Cook Inlet. Dr. Dall's opportunities for observations were necessarily limited, as the entire journey occupied but a part of the summer months. In his report[a] he gave not only the results of his field observations, but also a summary of all existing knowledge of the coal resources of Alaska. Dr. Dall's previous explorations in other parts of the Territory enabled him to include also a summary of the geology and paleontology of Alaska. In the last few years the discovery of the various gold placer fields has led to great activity in exploratory work in Alaska, and has added considerably to our knowledge of the geology of the Territory, especially of the interior.

It will be the purpose of the writer to briefly summarize such parts of Dr. Dall's and other reports as refer more directly to practical problems of coal supply and development in the Territory. The question of the distribution of the coal-bearing rocks involves a discussion of

[a] Report on the coal and lignite of Alaska, by William H. Dall: Seventeenth Ann. Rept. U. S. Geol. Survey, Part I, pp. 769-908.

the distribution of the Cretaceous and Tertiary formations of the region. These geologic relations of the coal-bearing strata will be treated as briefly as is consistent with the intricacy of the subject. As this report is for the most part purely a compilation, and has been rather hastily prepared, the writer wishes to disclaim any purpose of making an original contribution to a scientific discussion of the geologic problems.

GEOGRAPHIC SUBDIVISIONS.

GENERAL STATEMENT.

Alaska includes a number of natural provinces which are defined not only by their geographic positions, but also by striking differences of relief, of climatic conditions, and consequent variations in vegetation. These natural subdivisions of the Territory may be conveniently used in a discussion of the mineral resources.

For the purpose of this report the Territory will be divided into six provinces, as follows: Southeastern Alaska, southwestern Alaska, the Kuskokwim region, the Yukon Basin, northwestern Alaska, and northeastern Alaska.

SOUTHEASTERN ALASKA.

In southeastern Alaska is included the coastal belt bordering on the Pacific Ocean, extending northward from Dixons Entrance to Prince William Sound and including the Alexander Archipelago. It is bounded on the north and east, as far as Mount St. Elias, by the international boundary, and for convenience of discussion will be made to include the Copper River Basin. It is characterized by an irregular coast line and by rugged topography. Two mountain ranges separate this coastal belt from the interior. The St. Elias Range is the most extensive and rugged of these, and with its continuation, the Chugach Mountains, stretches from Cross Sound westward, nearly to the head of Cook Inlet. To the southeast, the submerged portion of this range is represented by the islands of the Alexander Archipelago. The second mountain system is the so-called "Coast Range," which extends parallel to the coast line from near the head of Lynn Canal, southeast into British Columbia. These mountains give rise to the many glaciers which are such characteristic features of the landscape of this region. Five rivers of considerable size find their sources in the interior beyond these coast mountains. Of these, the Copper River traverses the Chugach Mountains, and the Alsek River cuts across the St. Elias Range. The Chilkat River rises in the interior, flows parallel to the St. Elias Range, and empties into Lynn Canal. The Taku and Stikine rivers both have their sources beyond the Coast Range.

SOUTHWESTERN ALASKA.

Southwestern Alaska embraces the Aleutian Islands, Alaska Peninsula and adjacent islands, Kenai Peninsula, and the Cook Inlet region with drainage basins of its tributary rivers. The coast line is very irregular and is generally abrupt, the mountains rising almost directly from the sea. Besides the deep embayment of Cook Inlet, there are many minor indentations and embayments. The Aleutian Islands have similar types of shore line and are mountainous, often containing peaks of considerable height which are of volcanic origin. The islands mark a series of volcanic vents which are extended inland along the Alaskan Peninsula nearly to the head of Cook Inlet. This line of volcanic activity marks the Aleutian Range, which lies close to Cook Inlet and its connecting body of water, Shelikof Strait. To the west of this range is a rugged mountain mass which extends in a northeasterly direction from the neighborhood of Bristol Bay and seems to be coextensive with the great Alaskan Range. Kenai Peninsula, which separates Cook Inlet from Prince William Sound, is a rough mountain mass with very irregular coast line. Kadiak Island and its associated islands form a southwestern extension of the same type of topography, but the relief is not so great.

The only rivers of considerable size in this part of Alaska are those entering the head of Cook Inlet. The Sushitna River rises on the southern slope of the Alaskan Range and flows southward through a broad valley into Cook Inlet. The Matanuska, a somewhat smaller river, is also tributary to the upper part of Cook Inlet.

KUSKOKWIM REGION.

Under this heading is included an area lying west of Cook Inlet and east and south of the Yukon, and draining into southeastern Bering Sea, chiefly through the Kuskokwim River. The eastern part of this region is broken by a more or less irregular mass, which in its northern extension is a well-defined mountain system called the "Alaskan Range." To the west of these mountains is the broad basin of Kuskokwim River. A small area in the southern part of this region drains directly into Bering Sea by a number of short rivers.

YUKON BASIN.

Yukon River drains a large, irregularly shaped area lying in part in Alaska and in part in the British Northwest Territory and British Columbia. Its chief tributaries are the Koyukuk, Tanana, Porcupine, White, Pelly, and Lewes. The two last unite to form the Yukon proper, and their drainage basins lie entirely within Canadian territory. The headwaters of the Lewes lie 25 miles from Lynn Canal, while the head of the Pelly has its source near the head of the Stikine River.

The larger part of the basin is occupied by the dissected Yukon Plateau, which near the headwaters has an elevation of about 5,000 feet and falls off to the north near the Great Bend of the Yukon to about 2,500 feet. To the east of the plateau lies the mountain range which is the northern extension of the Rocky Mountains. This range continues nearly to the Arctic coast, then makes an abrupt turn to the west parallel to the coast, forming the Romanzof, Davidson, and De Long mountains, in which lies the Arctic Yukon watershed. On the southwest side of the Yukon Basin the Coast Range in its northwestern extension merges into the Yukon Plateau, while the great mountain mass of the St. Elias Range forms the barrier between the coast and the interior and in part also the watershed. This range continues northward to the head of White River, beyond which divide it is more sharply defined by the Nutzotin Mountains and the Alaskan Range, which separate the Yukon waters from those of the Copper and Sushitna rivers. In about longitude 150° the Alaskan Range makes a decided bend to the southwest, and from this point the Yukon Basin is bounded by a low range of mountains lying between the Tanana and Kuskokwim watersheds.

NORTHWESTERN ALASKA.

Under this heading is included a rather ill-defined area lying northwest of the Yukon Basin, which for the most part is drained by rivers flowing into the Arctic Ocean. Seward Peninsula, which is cut off from the mainland mass by Norton Sound on the south and Kotzebue Sound on the north, is an important topographic feature of this province. North of this is a minor peninsula, which has Point Hope as its western extremity. Several rivers drain from Seward Peninsula into Norton Bay, and a number of others into Bering Sea and the Arctic Ocean. Two rivers of considerable size flow into Kotzebue Sound—the Kowak on the south and the Noatak on the north.

Seward Peninsula is for the most part a dissected upland with a number of minor ranges. In the areas drained by the Noatak and the Kowak[a] rivers are a number of mountain masses extending in an east-west direction. From Point Hope and Cape Lisburne a low range of mountains stretches to the eastward, and is probably a westward extension of the Romanzof Mountains, which lie near the Arctic Ocean close to the international boundary.

NORTHEASTERN ALASKA.

This province has been but little explored. As used here it includes the drainage basins of the rivers which enter the Arctic Ocean between Point Barrow[b] and the international boundary. The largest of these

[a] This river is more generally known among prospectors as the "Kobuk" River.

[b] The accompanying map, being limited by the size of the pages of this report, does not extend quite far enough to the north to include Point Barrow.

rivers is the Colville, which has its source near the head of the Noatak. A range of considerable height separates this northerly drainage from the waters of the Yukon Basin. The geology and mineral resources of this region are entirely unknown, so it will receive no further description in this report.[a]

GEOLOGIC RELATIONS.

DESCRIPTION OF MAP.

The map (Pl. XXXV) summarizes the existing knowledge of the distribution of coal and of the coal-bearing rocks in the Territory. It will be noted that the occurrences of coal represented on the map are chiefly along the waterways, where the most detailed investigations have been made. This fact makes it probable that further exploration will show considerable extension of the coal-bearing horizons.

The coals of Alaska that are of commercial importance as far as known belong in two larger subdivisions of the geologic column, namely, the Mesozoic and the Cenozoic.[b] Those of the former are probably all of Cretaceous age, and those of the latter fall in the various divisions of the Tertiary.

In the Yukon Basin, where both Cretaceous and Tertiary beds carry workable coal seams, the incompleteness of the geologic studies makes it impossible to differentiate the beds of the two periods. On the accompanying map, therefore, the coal-bearing beds have been mapped as a unit, irrespective of their position in the geologic column. In the descriptions of the different localities, however, all the available facts in regard to the age of the beds will be presented.

Localities from which coal has been reported, but where no very definite information exists in regard to its exact location or its commercial value, have been indicated by descriptions printed on the face of the map. Areas of Cretaceous and Tertiary rocks which are not known to carry workable coal beds are also approximately indicated by brief lithologic descriptions on the map. This is done because it is believed that future investigations may show that coal exists in some of the beds that are now considered barren.

A study of the literature bearing on the geology of Alaska has led to some tentative conclusions regarding the geologic horizons of the workable coal seams found in different parts of the Territory. The commercial coals of southeastern and southwestern Alaska occur in the Tertiary, and chiefly in its lowest division. The coals of the

[a] Since the above was written Messrs. W. J. Peters and F. C. Schrader have made an exploratory survey from the Koyukuk to the Colville and the Arctic Ocean.

[b] The writer has described some impure coals associated with rocks of Carboniferous age in the Upper White and Tanana River basins, but these are believed to be of no commercial importance. The position of these is indicated on the accompanying map. Compare A reconnaissance from Pyramid Harbor to Eagle City, Alaska: Twenty-first Ann. Rept. U. S. Geol. Survey, Part II, p. 382.

Yukon Basin are less well known, but seem to be of both Cretaceous and Tertiary age. The Cape Lisburne coal of northwestern Alaska is probably Cretaceous, or at least Mesozoic.

DESCRIPTION OF TABLE OF SECTIONS.

All the available data regarding the succession of the Cretaceous and Tertiary beds in this region have been gathered together in the accompanying table. As the writers on Alaskan geology have only in rare instances given their results in the form of vertical sections, the matter presented in this table can be regarded as only approximately accurate. In most cases these vertical sections are only generalizations of sections having considerable horizontal extent. Where the succession of beds in formation has been described by the geologist, it has been so represented in the table, but in most cases the writers have confined their descriptions to generalizations of the lithologic characters, often without indicating the stratigraphic position of the various beds in the formation. In only a few instances were any estimates of thickness made, and these are included in the table. The arrangement of the sections in the table is geographic, the first being the Porcupine River section in northern Alaska, and the last being in the Queen Charlotte Islands, near the southeastern limit of Alaska.

MESOZOIC ROCKS.

Cretaceous Rocks.[a]

SUBDIVISIONS AND STRATIGRAPHIC POSITIONS.

Rocks which have been referred to the Cretaceous have a wide distribution in Alaska and adjacent portions of Canada. These have been described in different localities under various formation names[b] and have usually been assigned to the Lower Cretaceous. The paleontologic evidence obtained, as yet, is but fragmental, and, according to Dr. Stanton,[c] consists mainly of the identification of a single species *Aucella crassicollis* Keyserling, which has been found rather widely distributed in Alaska. This species marks a definite horizon in the Knoxville beds of the Lower Cretaceous of California, and also occurs in the Lower Cretaceous of Russia, but the genus *Aucella* occurs abundantly in the Upper Jurassic as well as the Lower Cretaceous, and the identification of a single species of that genus represented by a few imperfect and fragmentary specimens can not safely be depended on for separating Jurassic from Cretaceous rocks. It is probable that all

[a] The writer is indebted to Dr. T. W. Stanton for many important notes and suggestions bearing on this part of the report.

[b] See table of sections opposite this page.

[c] Twentieth Ann. Rept. U. S. Geol. Survey, Pt. VII, pp. 161, 168, and 309; also Geology of the Yukon gold district: Eighteenth Ann. Rept. U. S. Geol. Survey, p. 184.

Sections of Mesozoic and Tertiary beds in Alaska and adjacent portions of British Columbia.

			Porcupine River (McConnell[a]).		Mission Creek, Yukon River (Spurr[b]).		Lower Tanana and Yukon River (Spurr and Brooks[c]).		Lower Koyukuk and Yukon River (Schrader[d]).		North shore of Bristol Bay (Spurr[e]).	
			Formation	Lithologic character.	Formation.	Lithologic character.	Formation.	Lithologic character.	Formation.	Lithologic character.	Formation.	Lithologic character.
Tertiary.	Neocene.	Miocene or Pliocene.	Unconformity.	Sand, clay, gravel, and some lignite.	Twelve-mile beds. Unconformity.	Cross-bedded gravels and sands, with seams of lignite.	Palisade conglomerate. Unconformity.	Cross-bedded gravels and sands, fossil plants, probably Miocene or Pliocene.				
Tertiary.	Neocene.	Miocene.							Nulato sandstone, 200 feet +.	Brown sandstone, some lignitic matter, and igneous rocks.	Nushagak beds. Miocene fossils. Unconformity	Coarse sands, arkoses, and clays, partly consolidated.
Tertiary.	Eocene.				Kenai, 10,000 feet +. Unconformity.	Sandy argillaceous limestone and carbonaceous shale, with lignite seams; greenish sandstone, limestone, and coarse grit; massive conglomerate; Eocene fossil plants.	Kenai. Unconformity.	Greenish sandstone, clay shales, and seams of lignite, coarse conglomerate.	Kenai (?).	Conglomerate sandstones and grits, partly consolidated.		
Mesozoic.	Cretaceous.	Upper Cretaceous.		Sandsone and quartzite, several thousand feet thick, dark shales.					Upper Cretaceous.	Impure limestone, Upper Cretaceous fossils.		
Mesozoic.	Cretaceous.	Lower Cretaceous, possibly in part Juratrias.	Queen Charlotte Islands. Unconformity.	Alternating shales, sandstones, and conglomerate.	Mission Creek, 1,000 feet +. Unconformity.	Arenaceous limestone and Lower Cretaceous fossils. Compact granite slate. Black carbonaceous slate and coal seams. Fine sandstone and carbonaceous slate. Coarse gray sandstone and carbonaceous shale, coarse conglomerate.	Nilkoka beds, Cretaceous (?). Unconformity.	Red and green slates and sandstone. Fine conglomerate and sandstone.	Lower Cretaceous. Unconformity.	Impure limestones, tuffs, and igneous rocks. Cretaceous fossils.	Oklune series, probably Lower Cretaceous.	Impure limestones, shales, conglomerate arkoses, and igneous rocks.
			Paleozoic limestone and dolomite.		Carboniferous limestone and older metamorphic rocks.		Metamorphic schists, Paleozoic or older.		Paleozoic quartzites, black shales, and impure limestones.			

			Kenai Peninsula (Dall and Mendenhall[f]).		Skwentna River (Spurr[g]).		Copper River Basin (Schrader and Spencer[h]).		General section, southeastern Alaska (Dall[i]).		Atlin Lake, British Columbia (J. C. Gwillam[j]).		Queen Charlotte Islands, British Columbia (Richardson and Dawson[k]).	
			Formation.	Lithologic character.	Formation.	Lithologic character.	Formation.	Lithologic character.	Formation.	Lithologic character.	Formation.	Lithologic character.	Formation.	Lithologic character.
Tertiary.	Neocene.	Miocene or Pliocene.			Tyonek and Hayes River beds. Unconformity (?).	Clay and sand, brown lignite seams.								Gray feldspathic sandstone, with Miocene or Pliocene fossils, lignite seams.
Tertiary.	Neocene.	Miocene.					Tertiary volcanics.	Volcanic rocks, tufas, and lavas.	Astoria group (?) beds.	Brown Miocene sandstones, marine shells.				
Tertiary.	Eocene.		Kenai.	Sandstones, shales, and conglomerate; lower part contains lignite seams.	Yentna, probably Kenai. Unconformity.	Coarse conglomerate, lignite seams, and some igneous rocks.	Unconformity.		Unga beds. Kenai. Unconformity.	Conglomerate sand layers, fossil leaves. Bluish sandstone and shales, conglomerate with lignite seams.			Tertiary, probably chiefly of Kenai age and some Miocene. Unconformity.	Sandstones and shales, with many extrusives, tuffs, etc., some lignitic beds.
Mesozoic.	Cretaceous.	Upper Cretaceous.											Upper shale and sandstone. Conglomerate.	Brown and black arenaceous, calcareous shales, and sandstone, 1,500 feet. Conglomerate, gray and yellow sandstone, 2,000 feet.
Mesozoic.	Cretaceous.	Lower Cretaceous, possibly in part Juratrias.	Matanuska series, cut by igneous rocks. Unconformity.	Fine conglomerate and lignitic seams. Limestone, 300 ft. +, Lower Cretaceous fossils. Green shales. Conglomerate 1,000 feet +.	Tordrilla series. Cretaceous (?). Unconformity.	Black shale, often carbonaceous, arkose, impure limestone, and intrusives.	Kennicott. Unconformity.	Green sandstones. Black shale and impure limestones. Conglomerate and sandstone.			These beds are Cretaceous or Jurassic. Unconformity.	Greenish sandstone and some conglomerate. Lower beds contain more conglomerate. Cretaceous or Jurassic fossils.	Queen Charlotte Islands. Lower shales and sandstone. Coal. Unconformity. Agglomerate. Lower sandstone. Unconformity.	Black and gray shales, gray and yellow sandstone, and arenaceous sandstone, 5,000 feet. Coal seams. Tuffs and tuffaceous sandstone; green, gray, brown, and purple sandstone and agglomerate and effusive rocks, 3,500 feet. Tuffaceous sandstone and some calcareous layers, 1,000 feet.
			Metamorphic schists, probably Jurassic or Triassic.		Ancient and altered volcanic tuffs, carbonaceous chert, and arkose, probably Jurassic.		Shales and limestones, Triassic, Jurassic, or Paleozoic.				Mesozoic or Paleozoic igneous rocks.		Flaggy argillites, sometimes calcareous, of Triassic age.	

[a] Exploration in the Yukon and Mackenzie basins: Geol. Nat. Hist. Survey Canada, new series, Vol. IV, pp. 21 D and 127 D.

[b] Geology of the Yukon gold district: Eighteenth Ann. Rept. U. S. Geol. Survey, Pt. III, pp. 175 and 184. Exploration in the Yukon and Mackenzie basins: Geol. Nat. Hist. Survey Canada, new series, Vol. IV, p. 21 D.

[c] Geology of the Yukon gold district: Eighteenth Ann. Rept. U. S. Geol. Survey, Pt. III, pp. 188, 189, 199, and 200. Reconnaissance in the Tanana and White river basins: Twentieth Ann. Rept. U. S. Geol. Survey, Pt. VII, p. 472.

[d] A reconnaissance along Chandlar and Koyukuk rivers: Twenty-first Ann. Rept. U. S. Geol. Survey, Pt. II, p. 474.

[e] A reconnaissance in southwestern Alaska: Twentieth Ann. Rept. U. S. Geol. Survey, Pt. VII, pp. 173 and 174.

[f] Coal and lignites of Alaska: Seventeenth Ann. Rept. U. S. Geol. Survey, Pt. II, p. 788. Reconnaissance from Resurrection Bay to the Tanana: Twentieth Ann. Rept. U. S. Geol. Survey, Pt. VII, pp. 317 and 325.

[g] A reconnaissance in southwestern Alaska: Twentieth Ann. Rept. U. S. Geol. Survey, Pt. VII, pp. 153 and 172.

[h] Geology and Mineral Resources of a Portion of the Copper River District; a pamphlet published in 1901 by the U. S. Geological Survey, under authority of a resolution of Congress.

[i] Correlation papers—Neocene: Bull. U. S. Geol. Survey No. 84, pp. 233 to 237.

[j] Summary Report Geol. Nat. Hist. Survey Canada, 1901, p. 51.

[k] Geol. Nat. Hist. Survey Canada, 1872 and 1873, pp. 1–100. Geol. Nat. Hist. Survey Canada, 1878 and 1879, pp. 1 B to 101 B.

MAP SHOWING DISTRIBUTION OF COAL-BEARING ROCKS, ALASKA

BY ALFRED H. BROOKS

Scale

100 0 100 200 300 MILES

the Alaska beds from which *Aucella crassicollis* has been reported are Lower Cretaceous, though part of them may be Jurassic. For convenience of description, the Aucella beds will be here provisionally assigned to the Lower Cretaceous until their stratigraphic position has been determined.

Upper Cretaceous beds have been found at a few localities. McConnell[a] regards the highest members of the Cretaceous section on the Porcupine as probably Upper Cretaceous. Schrader[b] found Upper Cretaceous beds on the lower Koyukuk, and the higher part of the Queen Charlotte Island Cretaceous[c] is also Upper Cretaceous.

DISTRIBUTION.

The Cretaceous section has been studied in the Queen Charlotte Islands in greater detail than in any other part of this province. There the work of Richardson[d] and later of Dawson[e] has resulted in a division of the Cretaceous into various formations, shown in the table opposite page 526. The beds consist of conglomerate sandstones, shales, and agglomerates. Whiteaves,[f] who studied the paleontologic collections made by Richardson and Dawson, arrived at the conclusion that the formations are in part Upper and in part Lower Cretaceous. The Cretaceous rocks of Queen Charlotte Islands, as well as those of Vancouver Island lying to the south, include some valuable coal deposits.[g]

In the Atlin Lake region of British Columbia, which is drained by the Lewes River, Cretaceous rocks have been recently reported by J. C. Gwilliam.[h] He states that these beds include greenish sandstone and conglomerate, and that as far as known they carry no coals. Of this occurrence Dr. Stanton, in a personal letter, says:

> I have recently seen a few fragmentary fossils collected by Mr. Gwilliam in the Atlin Lake region, and they seem to be of early Jurassic age. They are probably from the beds referred to in the report cited.

Dawson many years ago mapped a number of areas of Cretaceous rocks along the Pelly and Lewes rivers,[i] and at several localities these

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[a] An exploration in the Yukon and Mackenzie basins: Geol. Nat. Hist. Survey Canada, new series, Vol. IV, 1888-89, p. 21 D; Cretaceous System in Canada, by J. F. Whiteaves: Trans. Royal Society of Canada, Vol. XI, Section IV, 1893, pp. 16 and 17.

[b] A reconnaissance along Chandlar and Koyukuk rivers: Twenty-first Ann. Rept. U. S. Geol. Survey, Pt. II, p. 474.

[c] Op. cit., pp. 12, 13; Geol. Nat. Hist. Survey Canada: Mesozoic fossils, Vol. I, Pt. III; On the fossils of the coal-bearing deposits of Queen Charlotte Islands, by J. F. Whiteaves, 1884; ibid., Pt. IV, 1900.

[d] Geol. Nat. Hist. Survey Canada, 1872-73, pp. 1-100.

[e] Geol. Nat. Hist Survey Canada, 1878-79, pp. 1 B-101 B.

[f] Geol. Nat. Hist. Survey Canada: Mesozoic fossils, Vol. I, Pt. III; On the fossils of the coal-bearing deposits of Queen Charlotte Islands, 1884. See also Mesozoic fossils, Vol. I, Pt. I, 1876, and Pt. IV, 1900, and Cretaceous System of Canada: Trans. Royal Soc. Canada, Vol. XI, Section IV, 1893.

[g] Mineral wealth of British Columbia, by G. M. Dawson: Geol. Nat. Hist. Survey Canada, Vol. III, Pt. II, p. 85 R.

[h] Rept. Geol. Nat. Hist. Survey Canada, 1901, p. 5[illegible].

[i] Yukon District and British Columbia: Geol. Survey of Canada, new series, Vol. III, Part I.

beds are known to carry coals. Dr. Stanton states that parts of these beds are doubtfully correlated with the Laramie and part with the Queen Charlotte Cretaceous.

In the Alexander Archipelago no Cretaceous rocks have thus far been found. In the Copper River Basin Schrader and Spencer[a] have recently given the name Kennicott to a series of green sandstones, black shales, and conglomerates. Fossils have been found in this formation which show that at least part of it is of Lower Cretaceous age. No coal has been found in the Kennicott.

Schrader's[b] Orca series consists of brown and gray sandstone, black limestone, arkoses interbanded with dark shale, and some conglomerate. This series was provisionally placed in the Lower Tertiary, but it now seems more likely that it is of Jurassic[c] age or older. The Orca series occupies considerable areas around Prince William Sound and the mouth of Copper River. As far as determined it carries no coal.

Near the headwaters of the Matanuska and in adjacent portions of the Copper River Basin, Mendenhall[d] has described the Matanuska series, consisting of fine conglomerates, limestones, green shales, and a basal bed of heavy conglomerate. In some localities these rocks carry lignite seams. The whole series is cut by igneous rocks. Fossils collected by Mendenhall from the Matanuska were determined by Stanton to belong with the beds here classed as Lower Cretaceous.

Spurr[e] has given the name Tordrillo series to a succession of black shales, often carbonaceous, arkoses, and impure limestones, with intrusives, which he found on the Skwentna River, a tributary of the Sushitna. These were not found to be coal bearing. The assignments of the Tordrillo to the Cretaceous is based on structural grounds, there being no paleontologic evidence.

In southwestern Alaska there are Mesozoic beds, some of which are probably Cretaceous, but so far as known they do not carry coals. Dr. Stanton has made the following report on some fossils from Herendeen Bay, collected by Ernest L. Locke:

The fossils from Herendeen Bay, Alaska, have been examined and found to consist of a number of specimens of *Aucella* and a fossil plant. The *Aucella* appear to be identical with *A. crasicollis* Keyserling, a Lower Cretaceous species common in Russia and in the Knoxville beds of California and Oregon. The plant has been sent to Professor Ward, who says it is a cycad, and compares it with Jurassic and Lower Cretaceous species.

The beds which have yielded these fossils are therefore almost certainly of Lower

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[a] Geology and Mineral Resources of a Portion of the Copper River District; a pamphlet published in 1901 by the U. S. Geological Survey under authority of a resolution of Congress.

[b] A reconnaissance of a part of the Prince William Sound and Copper River region: Twentieth Ann. Rept. U. S. Geol. Survey, Pt. VII, pp. 404-408.

[c] Geology and mineral resources of a portion of the Copper River district.

[d] Reconnaissance from Resurrection Bay to the Tanana: Twentieth Ann. Rept. U. S. Geol. Survey, Pt. VII, pp. 317, 325.

[e] A reconnaissance in southwestern Alaska: Twentieth Ann. Rept. U. S. Geol. Survey, Pt. VII, p. 153.

Cretaceous age, the only other possibility being Upper Jurassic. I would question, however, whether the coal of that neighborhood is of the same age. Some years ago Mr. C. H. Townsend, then naturalist on the United States Fish Commission steamer *Albatross*, brought back some of these Aucellæ and other Mesozoic fossils from Herendeen Bay, but he also brought some Tertiary invertebrates from the same neighborhood, and a collection of fossil plants in close proximity to the coal, which Professor Knowlton described as Eocene. These plants are described and figured in Proc. U. S. Nat. Mus., Vol. XVII, pp. 207–240, and they are also referred to by Dr. Dall in Seventeenth Ann. Rept. U. S. Geol. Survey, Pt. I, pp. 805–807.

Near the north shore of Bristol Bay, as described by Spurr, is a series of impure limestones, shale, conglomerates, and arkoses, with igneous rocks, to which he has given the name Oklune.[a] These he assigns to the Lower Cretaceous on stratigraphic evidence. One hundred miles to the north, in the Kuskokwim Valley, Spurr found a basal conglomerate succeeded by sandstones, arkoses, and carbonaceous shales, with some lignitic seams, which he grouped together as the Holiknuk series.[b] It contains plant remains and invertebrate fossils. The few fossils collected by Spurr indicate that these rocks are Lower Cretaceous.

In the Koyukuk River Basin, near the sixty-sixth parallel, some Lower Cretaceous rocks have been found by Schrader.[c] These consist of impure limestones, often pink or reddish in color, and often closely folded. So far as known these Cretaceous rocks carry no coals. Schrader also makes mention in the same report of Upper Cretaceous rocks, consisting of impure limestones, occurring near the mouth of the Koyukuk River and on the Yukon River. On his map, however, he has not attempted to differentiate these from the Tertiary rocks.

Dr. Stanton has furnished the writer with the following notes on the fossils collected by Schrader. The fossils from the Upper Koyukuk, near the sixty-sixth parallel, include *Aucella crasicollis* Keyserling from two localities, indicating the Lower Cretaceous age of these beds. The following species were obtained from a locality on the Yukon near the mouth of the Koyukuk:

Fossils found on Yukon River near mouth of the Koyukuk.

Ostrea sp.	Lucina ? sp.
Anomia sp.	Trigonia cf. T. leana Gabb.
Mytilus sp.	Corbula sp.
Pectunculus cf. P. veatchi Gabb.	Actæonella cf. A. oviformis Gabb.
Opis ? sp.	

Trigonia and *Actæonella* are very characteristic Cretaceous forms, and indicate a horizon much higher than that of the Aucella-bearing beds from the localities on the Upper Koyukuk.

[a] Reconnaissance in southwestern Alaska: Twentieth Ann. Rept. U. S. Geol. Survey, Pt. VII, p, 163.
[b] Op. cit., p. 159.
[c] A reconnaissance along Chandlar and Koyukuk rivers: Twenty-first Ann. Rept. U. S. Geol. Survey, Pt. II, p. 474.

The writer has given the name Nilkoka beds[a] to a succession of fine conglomerates, red and green slates, and sandstones that occur on the Lower Tanana. These were provisionally placed in the Paleozoic, but it now seems more likely that they are Cretaceous.

Spurr[b] and McConnell[c] report the presence of Cretaceous rocks on the Yukon near the international boundary. Spurr describes the succession of beds as being about as follows: Coarse basal conglomerate with carbonaceous shale, succeeded by fine sandstone, and these overlain by black carbonaceous slate and coal seams; above these are slates and limestones. He has given the name Mission Creek to this series, after the type locality, and gives 1,000 feet as a minimum thickness. These rocks are known to carry coals in some localities on the Yukon above the mouth of the Porcupine. It seems probable to the writer that detailed study will show that the same series is represented on the Lower Yukon below the mouth of the Porcupine.

On the Porcupine, McConnell[d] found a conglomerate sandstone and shale series, in part of Lower Cretaceous age, regarded by him as equivalent to those of Queen Charlotte Island. The upper members of the series are probably Upper Cretaceous.

In northwestern Alaska, Cretaceous rocks are known to occur only near Cape Lisburne. The plants from the coal seams of that vicinity have been assigned by Professor Ward[e] to the Mesozoic and probably to the Lower Cretaceous. We have but a few scattered notes on the geology of this locality. The coal veins are said to occur in sandstones and conglomerates.[f] Schuchert has reported the presence of (Upper) Silurian beds at Cape Lisburne.[g] Schuchert's determinations[h] are

[a] A reconnaissance in the Tanana and White River basins: Twentieth Ann. Rept. U. S. Geol. Survey, Pt. VII, p. 472.

[b] Geology of the Yukon gold district: Eighteenth Ann. Rept. U. S. Geol. Survey, Pt. III, pp. 175–184.

[c] An exploration in the Yukon and Mackenzie basins: Geol. Nat. Hist. Survey Canada, new series, Vol. IV, 1888–89, p. 21 D.

[d] An exploration in the Yukon and Mackenzie basins: Geol. Nat. Hist. Survey Canada, new series, Vol. IV, 1888–89.

[e] Distribution of fossil plants, by Lester F. Ward: Eighth Ann. Rept. U. S. Geol. Survey, Pt. II, p. 926.

[f] Coal deposits of Alaska, by Winthrop Packard: Colliery Guardian, Nov. 30, 1900, Vol. LXXX, No. 2083.

[g] Report on Paleozoic fossils from Alaska, by Charles Schuchert: Seventeenth Ann. Rept. U. S. Geol. Survey, Pt. I, pp. 899–900.

[h] Since the above was written, Mr. Schuchert has received some interesting fossils from the Cape Lisburne region, collected by Mr. H. D. Dumars and presented by Mr. A. C. Maddren, of Seattle, Wash. In a letter Mr. Schuchert says:

"There is an interesting coral fauna of Middle Devonian age from 'limestone of cliffs 4 miles south of Cape Lisburne, just south of the mouth of a considerable stream. The rocks strike east and west, and dip south at 45°' (Dumars). This limestone has *Endophyllum*, two species; *Syringopora* near *S. tabulata; Syringopora* near *S. perelegans; Diphyphyllum* near *D. simcoense; Diphyphyllum* near *D. stramineum; Zaphrentis*, probably two species.

"'Underneath' the coral limestone cliff, 'about 500 yards north of the limestone, coal occurs in shale.' In the shale 'and associated with a 4 feet seam of coal' was found a small species of *Lepidodendron*, which Mr. David White tells me is related to *L. chemungense*. It indicates either Upper Devonian or Lower Carboniferous age for the shale. Since the coral limestone is of Middle Devonian age, this shale with coal must lie above the limestone and not 'underneath,' as stated by Mr. Dumars.

"At the Corwin mine locality, 30 miles east of Cape Lisburne, Mr. Dumars 'picked up on the beach' from fossils collected by Fisher and Kupreanof, and reported by Grewingk. The Mesozoic and Paleozoic beds are apparently found very near together, but what their relation is must be left for future determinations.[a]

THICKNESS.

Dawson has placed the thickness of the Lower Cretaceous beds on Queen Charlotte Island at 9,500 feet and the Upper Cretaceous at 3,500 feet. This is the only definite measure of thickness which has been made. Spurr places the minimum thickness of the Mission Creek series at 1,000 feet and McConnell states that the upper member of the Cretaceous on the Porcupine is several thousand feet in thickness. What little evidence there is available seems to point toward the conclusion that there is a thinning out of the Cretaceous toward the northwest.

STRATIGRAPHIC RELATION.

Wherever the Cretaceous formations have been found in contact with the underlying rocks, an unconformity has usually been found between the beds of the two ages. In many instances there is unmistakable evidence of the existence of an erosional interval below the lowest member of the Cretaceous. The underlying rocks are often closely folded and highly metamorphosed, while the Cretaceous beds are but little altered. They are also found overlying beds of various ages. These facts, which are brought out in the table of sections, go to show that in Mesozoic but pre-Cretaceous times there was a period of dynamic activity which folded and metamorphosed the rocks and that some erosion took place previous to the deposition of the lowest Cretaceous beds.

Dawson has noted a slight unconformity[b] between the two upper divisions of the Lower Cretaceous. This seems to be of a local character and has not been noted elsewhere in the province.

LITHOLOGIC VARIATIONS.

Though the data are very incomplete, a few broad generalizations concerning the horizontal variations in the Cretaceous beds may perhaps be ventured. Almost everywhere where the base of the Cretaceous has been studied, it is found to consist of heavy conglomerate

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a small form of *Stigmaria ficoides* indicative of Carboniferous age. There is therefore in this region a formation of Carboniferous age.

"At the Corwin mine Mr. Dumars gathered a very interesting lot of fern plants from shale and sandstone. He writes that 'the rocks are made up of shales, sandstones, and conglomerates,' and that 'several of the coral beds are 10 or more feet in thickness.' These plants are probably of early Mesozoic age."

[a]Since the above was written, Mr. F. C. Schrader has studied a geologic section extending from the Koyukuk northward to the Arctic Ocean. In this section he found both Mesozoic and Tertiary rocks. A description will be found in his forthcoming report.

[b]Geol. Nat. Hist. Survey Canada, 1878-79, p. 67 B.

whose pebbles can usually be traced to a local source in the older formations. The character of this basal conglomerate and its distribution suggest that in early Cretaceous time, at least, the sediments were of a littoral character, and that in the sea in which they were deposited there were many land masses above water which afforded sediments.

A study of the Cretaceous sections shows them to be made up predominantly of coarse material. Conglomerates and sandstones are abundant, while shales and limestones are relatively rare. On the Koyukuk alone the Cretaceous is represented by limestone beds. In the Queen Charlotte Islands considerable volcanic sedimentary material is found in the rocks of this age, but is relatively rare in other localities. Igneous intrusive rocks are not uncommon. The unconformity which separates the Cretaceous from the Tertiary rocks will be referred to below.

DEFORMATION AND METAMORPHISM.

Since the Cretaceous sediments were laid down they have become consolidated and more or less folded. The amount of alteration to which they have been subjected varies greatly in different localities. As an example, the rocks of the Tordrillo and Matanuska series are often much altered and closely folded, while the Cretaceous rocks of Queen Charlotte Island, upper Lewes River, and the Koyukuk are less folded and comparatively little altered. In the regions of greater metamorphism igneous intrusives are not uncommon. So far as determined, the presence of the intrusives seems to be rather a resultant of the fracturing of the sediments during their deformation than the source of their metamorphism. The evidence points toward the conclusion that the deformation of the Cretaceous rocks differed very much in intensity in different parts of the province.

STRUCTURE.

The structure of but few Cretaceous areas has been determined. In some localites, as on the Lewes River, the strata are known to occur as a series of broad, open folds, and in others, as on the Yukon, they are closely folded, faulted, and jointed.

POSITION OF COAL.

In the Queen Charlotte section the coal occurs at about the middle of the Lower Cretaceous beds (compare table of sections). At no other locality has the horizon of the coal been determined, but such evidence as is available suggests an equivalent position of the coal.

Dr. Stanton has furnished the writer with the following note in regard to the positiou of known coal-bearing horizons in the Pacific coast and in Canada:

These are, in the Lower Cretaceous, the Queen Charlotte, on the islands of British Columbia, which is correlated with the Kootanie in the Rocky Mountain region; in the Upper Cretaceous, the Naniamo formation on Vancouver Island, which is correlated with the Chico formation of California, the Pelly River beds near the middle of the Upper Cretaceous in Manitoba and the Northwest Territory, and the Laramie at the top of the Cretaceous in the Rocky Mountains. This horizon is doubtfully recognized in the north on the Yukon, Pelly, and Porcupine rivers.

SUMMARY.

Cretaceous beds are extensively developed in the region under discussion. Some limestones occur in them, but arenaceous sediments, such as sandstones and conglomerates, are more characteristic rock types. The greater part of the sediments which have been referred to the Cretaceous are shallow-water and littoral deposits. It seems probable that the Cretaceous rocks have not mantled the entire region in which they were so widely distributed and that there were a number of land masses in the Cretaceous sea.[a] Such conditions would be favorable for the accumulation of coal deposits. The coal of the Cretaceous rocks seems to have been laid down in basins of rather limited extent.

Igneous intrusives are not uncommon in the beds of this age. The degree of deformation and metamorphism to which the Cretaceous rocks have been subjected varies greatly.

TERTIARY ROCKS.

SUBDIVISIONS AND STRATIGRAPHIC POSITIONS.

The Tertiary rocks have a wide distribution in Alaska and have been described by a number of writers. Dr. Dall was the first to make a systematic attempt to subdivide and correlate the strata of this age. He differentiates three groups, of which the lowest is the Kenai[b] group, consisting of bluish sandstones, shales, and conglomerates with lignitic seams. To the upper member of the Kenai group, consisting of conglomerate and sand layers, he has given the name "Unga beds." The Kenai rocks were at first supposed to be Miocene, but later determinations by Knowlton place them in the Upper Eocene.[c] The plant remains in the Kenai are terrestial and fresh-water forms.[d] Above the Kenai occur brown sandstones containing marine shells of Miocene age, which Dr. Dall has correlated with his Astoria group of Oregon.[e] To these Miocene sandstones of the Yukon Basin he has given the name "Nulato," from the type locality. Dall's subdivisions have been adhered to by other geologists except in minor details. Spurr has added as another subdivision of the Tertiary some beds which he believes to be younger than the Nulato sandstone and of probably Upper Miocene or Pliocene age. These will be referred to below.

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[a] On late physiographical geology of the Rocky Mountain region in Canada, by George M. Dawson: Trans. Royal Soc. Canada, Sec. IV, May, 1890.

[b] Correlation papers; Neocene, by W. H. Dall: Bull. U. S. Geol. Survey No. 84.

[c] Geology of the Yukon gold district: Eighteenth Ann. Rept. U. S. Geol. Survey, Pt. III. Also Fossil flora of Alaska: Proc. U. S. Nat. Mus., Vol. XVII, pp. 207-240.

[d] Dall, op. cit., p. 237.

[e] Op. cit., p. 233.

DISTRIBUTION.

Tertiary rocks have a wide distribution in southeastern Alaska and in adjacent portions of British Columbia. Dawson reports Tertiary beds on Graham Island[a] and on all the islands of the Queen Charlotte group. They consist of coarse, sandy beds with some conglomerate, considerable volcanic material, and some lignitic beds. These rocks are provisionally correlated with the Kenai beds. At one locality on Graham Island,[b] sandstones containing fossils of Miocene or Pliocene age were found. These also contained some lignitic seams.

Conglomerates, sandstones, and shales belonging to the Kenai group have been found in the northern half of the Alexander Archipelago,[c] and at Kasaan Bay, Prince of Wales Island. These occurrences are shown on the map (Pl. XXXV), the rocks being mapped as coal-bearing formations. To the west of the Alexander Archipelago lignitic rocks are found at Lituya Bay,[d] overlain by Miocene sandstone belonging to the Astoria group. Lignite-bearing rocks are found at Yakutat Bay which are probably Tertiary,[e] but their age has not been determined.

Between Icy Bay and Controller Bay coal-bearing rocks which have been provisionally assigned to the Kenai have been reported by F. H. Shepherd.[f] These beds are said to be considerably metamorphosed and to carry abundant plant remains. Near Cape Yaktag a sandstone has been found containing Miocene fossils.[g]

In the Copper River Basin the Tertiary[h] age is represented by a vast thickness of volcanic rocks, including both lavas and tuffs, and containing no true sediments. The same conditions probably held true during Tertiary times[i] along the northern front of the St. Elias Range, though there the effusives are associated with sediments which have been provisionally assigned to the Tertiary.

The type locality for the Kenai group is on the western side of the peninsula from which it takes its name. Here the Kenai, consisting of conglomerate sandstone with numerous beds of lignite, according to Dall,[j] overlies in some places Cretaceous rocks, in others meta-

[a] Geol. Nat. Hist. Survey Canada, 1878 and 1879, p. 85 B.

[b] Op. cit., p. 86 B.

[c] Coal and lignites of Alaska, by Wm. H. Dall: Seventeenth Ann. Rept. U. S. Geol. Survey, Pt. I, pp. 772–782.

[d] Op. cit., pp. 763–784.

[e] Dall, op. cit., p. 784.

[f] Reconnaissance in southwestern Alaska, by J. E. Spurr: Twentieth Ann. Rept. U. S. Geol. Survey, Pt. VII, p. 263.

[g] Op. cit., p. 264.

[h] Geology and Mineral Resources of a Portion of the Copper River District, by F. C. Schrader and Arthur C. Spencer; a pamphlet published in 1901 by the U. S. Geological Survey, under authority of a resolution of Congress.

[i] A reconnaissance from Pyramid Harbor to Eagle City, by Alfred H. Brooks: Twenty-first Ann. Rept. U. S. Geol. Survey, Pt. II, pp. 362–363.

[j] Op. cit., p. 788.

morphic rocks, which are probably Jurassic or Triassic. Under the name Yentna beds[a] Spurr has described some coarse sandstones and conglomerates with shales and lignites, which occur near the mouth of the river of the same name. These he regards as being probably of the same age as the Kenai. Spurr also found beds of clay, sand, and brown lignite in the same region, which he regarded as being younger than the Yentna beds. To these he has given the name Tyonek beds and Hayes River beds, after the different localities in which they have been found. Eldridge[b] mapped the Tyonek beds as part of the Kenai.

Eldridge[c] also reports Kenai rocks on the Sushitna, 100 miles from Cook Inlet. This same formation is known to occur at various points along the eastern margin of the Alaskan Peninsula[d] and the adjacent islands, as is also the Astoria group. In the Aleutian Islands the Tertiary seems to be represented chiefly by volcanic rocks, though Dall[e] reports some sediments.

Miocene fossils have been found in some partially consolidated coarse sandstones, arkoses, and clays on the north shore of Bristol Bay, to which Spurr[f] has given the name Nushagak beds. On Nunivak Island and adjacent portions of the mainland coal-bearing beds, which are probably Kenai,[g] have been reported. On the island they are largely covered by basalts. The following is quoted from Dall:[h]

> In the Yukon Valley (lower) and thence to the shores of Norton Sound a large area is occupied by lignite and leaf-bearing sandstones of the Kenai group, a smaller portion of which are overlaid by the Nulato marine sandstones, analogous to the Crepidula bed of Unga in age, but containing a different series of fossil shells.

Near the mouth of the Koyukuk[i] Schrader found the Nulato sandstone closely associated with Upper Cretaceous beds. On the Upper Koyukuk,[j] there are considerable areas of conglomerates and sandstones containing lignites which are believed to be of Kenai age. It is probable that the same series[j] occurs in the Chandlar Valley.

In the lower ramparts of the Yukon, Spurr[k] found Kenai beds, consisting of greenish sandstones, clay, and shales, with coarse conglomerate and seams of lignite. Below the mouth of the Tanana are beds of cross-bedded gravel and sands which have yielded some plant

[a] Reconnaissance in southwestern Alaska: Twentieth Ann. Rept. U. S. Geol. Survey, Pt. VII, p. 172.

[b] A reconnaissance in the Sushitna Basin and adjacent territory, by George H. Eldridge: Twentieth Ann. Rept. U. S. Geol. Survey, Pt. III, p. 17.

[c] Op. cit., p. 17.

[d] Dall, op. cit., pp. 797–811.

[e] Op. cit., pp. 811–814.

[f] Reconnaissance in southwestern Alaska: Twentieth Ann. Rept. U. S. Geol. Survey, Pt. VII, pp. 173–174.

[g] Coal and lignite of Alaska: Seventeenth Ann. Rept. U. S. Geol. Survey, pp. 814–815.

[h] Correlation papers; Neocene: Bull. U. S. Geol. Survey No. 84, p. 245.

[i] A reconnaissance along Chandler and Koyukuk Rivers: Twenty-first Ann. Rept. U. S. Geol. Survey, Pt. II, p. 478.

[j] Op. cit., p. 477.

[k] Geology of the Yukon gold district: Eighteenth Ann. Rept. U. S. Geol. Survey, pp. 188–189.

remains of Miocene or Pliocene age. To these beds Spurr[a] gave the name Palisade conglomerate. Near the international boundary, on the Yukon, the Kenai[b] is again found considerably developed. The basal member near the mouth of Mission Creek is a massive conglomerate, above which are greenish sandstones, impure limestones, carbonaceous shales, and lignites. In the vicinity are some cross-bedded gravels and sands with lignites, which Spurr[c] has called the Twelvemile beds, and has provisionally correlated with his Palisade conglomerate and with some Tertiary sediments found by McConnell[d] on the Porcupine River near the international boundary. Above these localities on the Yukon, Tertiary beds have been recently reported by McConnell[e] on the Klondike and Indian rivers.

In northwestern Alaska we have only very limited knowledge of the development of Tertiary rocks. Mendenhall[f] reports lignitic rocks on the Tubutulik River and some soft sandstones on the Koyuk River in the eastern part of the Seward Peninsula, which he considers to be Tertiary. On the Kowak River[g] lignites are known to be associated with conglomerates and sandstones, which are probably of Tertiary age. The writer is indebted to Mr. L. M. Prindle for two fossil leaves from the Kowak River. These occur in a siliceous shale, associated with grit and conglomerate, with scattered carbonaceous material. The locality is about 25 miles up Shunguak Creek, which is tributary to the Kowak from the north about 250 miles from Kotzebue Sound. These fossils are fragmentary, but Dr. Knowlton is inclined to assign them to the Tertiary.

The results of Mr. Schrader's work in the Colville River Valley and along the north Arctic coast are not yet available. He has informed the writer, however, that he found both Mesozoic and Tertiary rocks in this northern region. The Mesozoic beds are confined to the mountains, and the Tertiary beds go to make up the Arctic coastal plain east of Point Barrow.

THICKNESS.

No measurement of the thickness of any complete section of Tertiary has been made. On the Yukon, near Mission Creek, Spurr[h] estimated that the Kenai rocks might have a thickness of 10,000 feet. Near the Unalaklik on Norton Bay Dall[i] measured 2,000 feet of Tertiary strata. On Cook Inlet their thickness may be several thousand feet.

[a] Op. cit., pp. 199–200.
[b] Op. cit., pp. 185–188.
[c] Op. cit., pp. 196–197.
[d] Geol. Nat. Hist. Survey Canada, new series, Vol. IV, 1888–89, p. 127 D.
[e] Summary Report: Geol. Nat. Hist. Survey Canada, 1901, pp. 44, 48.
[f] Reconnaissance of Norton Bay region: U. S. Geol. Survey, 1901.
[g] Cruise of the Corwin, 1885, p. 48.
[h] Geology of the Yukon gold district: Eighteenth Ann. Rept. U. S. Geol. Survey, p. 194.
[i] Correlation papers; Neocene: Bull. U. S. Geol. Survey No. 84, p. 246.

The younger Tertiary beds have a thickness of several hundred, or, at most, a thousand feet. In the Copper River Basin[a] the accumulation of Tertiary volcanics probably has a thickness of many thousand feet.

DEFORMATION AND METAMORPHISM.

The Kenai is usually gently folded and locally considerably faulted. The faulted regions are those which lie in proximity to recent volcanic activity. The Kenai beds are indurated, but rarely metamorphosed. Exceptions to this rule are assignable to the metamorphic action of intrusive rocks. The Nulato sandstone is somewhat indurated and usually gently folded. The Miocene-Pliocene rocks show evidence of having suffered slight disturbances. Their beds are often entirely unconsolidated.

STRATIGRAPHIC RELATIONS.

The Tertiary beds are always found to overlie the older rocks unconformably. They are found resting not only on the Cretaceous but also on many of the older series. Spurr has pointed out that the youngest Tertiary formations, which have been provisionally placed in a Miocene-Pliocene group, bear an unconformable relation to the beds which they overlie. It has not been determined whether this second unconformity is local or widespread. The facts suggest that they may represent deposits formed during the erosion of the peneplain which is now partially preserved in the dissected Yukon Plateau.

LITHOLOGIC VARIATIONS.

The oldest Tertiary formation is the Kenai, which is nearly everywhere represented by coarse conglomerates with sandstones and some shales. The character of the sediments suggests littoral deposits, and the almost universal presence of lignite suggests shallow-water conditions. Like the Cretaceous, which they resemble in physical character, the Kenai rocks probably have not mantled the entire region in which they are now found, but were deposited in more or less isolated basins along a continental margin. The Nulato sandstone is of different character, and probably originally formed a continuous covering in the region where it is now found, and was subsequently partly removed by erosion. The Miocene-Pliocene beds are most probably purely local deposits which were laid down in lakes or along rivers.

POSITION OF COALS.

Lignitic seams are widely distributed in the rocks of this age. Those occurring in the Kenai are the only ones having commercial importance

[a] Geology and Mineral Resources of a portion of the Copper River District, by F. C. Schrader and Arthur C. Spencer; a pamphlet published in 1901 by the U. S. Geological Survey, under authority of a resolution of Congress.

at present. The best coal seams probably occur in the lower part of the Kenai formation. In the Puget Sound region[a] the coal-bearing Tertiary beds are believed to be also of Eocene age.

SUMMARY.

In southeastern Alaska Tertiary sediments are found in the northern part of the Alexander Archipelago, at Prince of Wales Island, and along the western margin of St. Elias Range. In the Copper River region the Tertiary is represented by volcanic rocks. Sediments of this age are found near the head of the Sushitna and probably in the adjacent portions of the Tanana Valley. They are extensively developed in southwestern Alaska, and with associated volcanics form the Aleutian Islands. The highest point on the Yukon where they have been found is on Indian River. Future explorations will probably show extensive Tertiary deposits in northern and northwestern Alaska. The earliest deposits of this period are the Kenai beds, containing fresh-water plant remains; later the Nulato marine sandstone was deposited. The youngest beds of Miocene-Pliocene age are probable local accumulations in lakes.

Igneous rocks are associated with the Tertiary sediments, sometimes almost to the exclusion of the former. The deformation of the Tertiary beds is, as a rule, very slight. Coal is widely distributed in all the Tertiary formations, though the workable seams are probably confined to the Kenai.

THE COAL.[b]

SOUTHEASTERN ALASKA.

GENERAL STATEMENT.

The coal-bearing formations of southeastern Alaska nearly all belong to the Kenai division of the Tertiary. The only exceptions are some lignitic veins occurring in Cretaceous rocks on western tributaries of Copper River. It has already been shown that the Kenai rocks have a wide distribution in this part of the Territory, and nearly everywhere carry some coal. They are found in the belt running between the coast and the St. Elias Range in a southwesterly direction from the vicinity of Controller Bay, and have been found at intervals as far as Lituya Bay near Cross Sound. They have also been found on the eastern margin of Barinof Island, on Admiralty Island, on Kuiu Island, on Kupreanof Island, and on the adjacent mainland. In general character they vary considerably, but are usually made up of sandstones and conglomerates. They have received relatively but

[a] Some coal fields of Puget Sound, by Bailey Willis: Eighteenth Ann. Rept. U. S. Geol. Survey, Pt. III, pp. 393–436.

[b] For analyses of coals, see tables pp. 549–550 and 565.

little deformation; are usually gently folded and sometimes faulted. In the Alexander Archipelago they overlie an older series made up of metamorphic rocks, which are occasionally carbonaceous, but do not carry coals, so far as known. Prospecting for coal should be confined to the younger series, made up of conglomerates, sandstones, and shales. Areas should be sought where the rocks are little disturbed, as the faulting which often accompanies the deformation breaks the continuity of the seams and makes mining unprofitable.

The Comax and Nanaimo coal fields of Queen Charlotte and Vancouver islands, as have been shown, occur in rocks of Lower Cretaceous age. These include anthracitic, bituminous, and lignitic coals. No beds belonging to this period have been found in the panhandle of southeastern Alaska.

ALEXANDER ARCHIPELAGO.

The most extensive explorations for coal in the archipelago have been made on Kootznahoo Bay, a deep indentation on the western side of Admiralty Island. Dall[a] describes the bay as affording good facilities for navigation, with the exception of the narrow entrance, which has strong tidal currents. The land in the neighborhood is rather low and wooded. The bed rock is shale and sandstone of the Kenai formation. Near the entrance the rocks are crumpled and faulted. The deformation decreases toward the northeast, and near McCluskey's mine the beds are found to be only gently folded, being nearly horizontal.

At the Sepphagen mine, on Favorite Bay, the southern arm of Kootznahoo Inlet, the coal seam is said to be about 1 foot thick and to occur in friable sandstones and soft shales. A small shaft was sunk on this vein of lignite,[b] but in 1895 the work had been abandoned. Dall[c] is of the opinion that the coal was in a small pocket and soon exhausted. On the west side of the bay a coal seam a few inches thick occurs in a reef which is covered at high water. Dall notes a seam of coal, 6 to 8 inches thick, on a small island. Between the two arms of Favorite Bay the associated sandstones are gently folded and faulted. At Point Sullivan, near the entrance to the bay, a shaft has been sunk 120 feet. The lignite, which is of low grade, is said to occur in two seams separated by 6 or 8 inches of shale. The associated gray shales are much slickensided. Analysis shows this coal to be of poor quality. On the southern shore of Mitchell Bay, the northern arm of the inlet, some small coal seams have been found. One, about 5 inches in thickness, occurs in hard sandstone on a small embayment just west of Passage Island. "A similar seam, 4 inches thick, and another, 4 to 6 inches

[a] Coal and lignite of Alaska: Seventeenth Ann. Rept. U. S. Geol. S rvey, Pt. I, p. 776.
[b] For composition see table, page 549.
[c] Op. cit., p. 778.

thick, are reported to exist on the southeast shore of the bay, but these, of course, have no commercial value."[a]

The Meade and Mitchell seam, which is a lignite containing much amber, occurs on "Davis Creek," a southeast arm of Mitchell Bay. Dall[a] describes this locality as follows:

There are at present two tunnels, 100 yards or more apart. The western tunnel (Mitchell) has been timbered, but is now full of water and the roof crushed in, probably on account of the decay of the timbering. The visible seam near high-water mark averages 1 foot in thickness, but is much contorted. One hundred feet west of the tunnel the seam turns vertical, bifurcates, and then runs out to a feather-edge. Dip, SE. flat, variable; strike, 25° NE. Above the coal the rock is almost wholly sandstone, without fossils; below, shale, with leaf impressions and vegetable remains. The eastern tunnel (Meade) is in similar rock and is similarly situated, but the strata are somewhat less contorted. The coal is about 1 foot thick. * * *

As noted by Bryant and others, in the small fissures of the coal a good many grains of fossil resin or amber were perceptible, and occasionally a small pocket holding a teaspoonful of this yellowish, coarse, powdery material occurred. No large masses of it were noticed, though it is doubtless true, as reported, that they are occasionally found.

The Brightman and De Groff seam is on Lighter Creek, about 1½ miles to the southeast. There at the time of Dall's visit the developments consisted of an abandoned tunnel 100 feet in length. A seam of shaly lignite, about 14 inches thick, is included between two layers of hard sandstone beds. Dall considers the seam worthless.

The most promising locality is the Firestone mine, or McCluskey's seam, as it is called. This is a good lignite, which has had considerable local use. The mine is situated on a southeasterly arm of Kanalku Bay, a southeasterly arm of Mitchell Bay. The following is quoted from Dall's description:[b]

In a small cove at the head of the left arm of this inlet, farther east than any of the other locations, is an outcrop of coal which has been stripped and prospected by Mr. James McCluskey. There are two principal outcrops of coal. One, at the foot of a small vertical bluff, dips at about the angle of the beach, 25° SE., with a strike 40° NE. The rock above it is a coarse sandstone without fossils. The seam is 18 inches thick, and is visible from low-water to about high-water mark or a little farther. It has been excavated along its face for a depth of 2 feet and a distance of 100 feet. In the beach, and normally covered by the sand and gravel, are several other parallel seams of coal, separated by variably thick beds of shale and slaty sandstone. The upper layer is the best and clearest, and does not exceed a foot in thickness. Below this seam is 6 or 8 feet of shale, and then a parallel seam of brown lignite mixed with bright coal and thin leaves of shale. This contains many particles of fossil resin and impressions resembling woody fiber. Owing to the wash over it, the full extent and uniformity of the seam could not be distinctly seen, but it appeared to include about 3 feet, with the central portion somewhat more shaly than the rest. Whether this mass is a local thickening of a seam elsewhere thinner, or part of a uniform bed, can be determined only by more extensive exploration. The rocks about this mine are less disturbed than in the more western portions of the

[a] Op. cit., p. 780. [b] Op. cit., p. 782.

area about the inlet, and the prospect of continuity in the veins is therefore somewhat better.

This outcrop is the only one in the inlet in which work has been recently done, and nearly 100 tons of coal have been taken out. The coal has met with a ready sale locally.

The more recent developments at the Firestone mine show a 16-foot seam, containing about 9 feet of coal and 6 feet of impurities.

Some coal developments have been made near Point Gardiner, at the southern end of Admiralty Island. At this point the carbonaceous beds, including lignite and impurities, are about 7 feet in thickness. Some mining was done near Point Gardiner[a] a number of years ago, but the opening was abandoned, as the rocks proved to be much broken and faulted and the coal not of good quality. Since 1898 prospecting in the vicinity has been renewed, and in 1900 considerable development was done, though the enterprise had not reached a producing stage.

At Coal Bay, an arm of Kasaan Bay, on the east side of Prince of Wales Island, lignite has long been known to occur. The writer has made a brief examination of this locality. A soft feldspathic sandstone overlies the older metamorphic rocks unconformably. The sandstone is gently folded and contains some small seams of lignite. The lignite is of good quality, but the largest seam observed, which was about one-half mile from the head of the bay, is only 8 inches thick. No fossils were found in these beds, but the rocks are believed to be of Kenai age.

On Kuiu Island near Port Camden there are said to be several veins of coal about 6 inches thick. On the western coast of the same island Dr. Dall mentions rocks of the coal-bearing formation. As yet no seams have been reported from this locality. At Whale Bay, Barinof Island, coal-bearing rocks of the Kenai formation are said to occur.

LITUYA BAY.

Near this bay rocks of the Kenai formation have been found. Coal seams have been reported, but nothing has been developed which is of commercial importance. The coal is said to be a bright lignite.

YAKUTAT BAY.

On the northwest shore of Yakutat Bay coals have been reported and an attempt was made at development. In the adjacent region, on the shores of Disenchantment Bay,[b] a bright lignite vein of good quality was found about ten years ago, and some prospecting was done by Jack Dalton, but it was abandoned because of its distance from deep water.

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[a] Op. cit., p. 773. [b] Population and Resources of Alaska, Eleventh Census, p. 230.

CONTROLLER BAY AND ICY BAY.

Coal from this region was reported to Mr. Spurr by Mr. F. H. Shepherd, of Nanaimo, British Columbia.[a] Here there is said to be one field which lies adjacent to the shores of Controller Bay and reaches from Cape Martin to Chilkat village, and another reaching 40 miles westward from Icy Bay. The rocks are believed to be altered Tertiaries, probably Kenai. They are said to be more altered as they leave the coast and approach the mountain front. Some of the coal seams are said to reach a thickness of 27 feet, while many are from 10 to 12 feet in thickness. The coal possesses a bright, black luster and conchoidal fracture, and has all the characteristics of semianthracite with the exception of hardness and specific gravity. In the second field, near Icy Bay, Neocene rocks have been found which are said to contain petroleum. Petroleum is also reported from the vicinity of Catalla[b] and from Kayak Island. Schrader and Spencer[c] report a good quality of coal, a semianthracite, from the head of Chilkat River, which reaches the coast near Kayak Island.

On Kayak Island,[c] near Controller Bay, coal has been found which is said to be a lignite of good character, and is probably a part of the same field as that to the north. Considerable prospecting has been done on the island, but no developments have been made.

REGION TO THE WEST OF CONTROLLER BAY.

In the region adjacent to the Copper River and Prince William Sound no workable coal deposits have been found and Tertiary sediments are not present. Some rocks described by Mendenhall in the Copper River Basin, and presumably of Cretaceous age, are known to carry coal, but have not thus far developed any seams of commercial importance. Of this region Mendenhall says:[d]

> Along the upper course of Bubb Creek [lying in the Copper River Basin], as within the valley of the Matanuska, thin coal seams may occasionally be seen interbedded with the shales and sandstones forming the stream bluffs.

Coal is also reported from the Chistochina and Gakena rivers,[e] both tributary to the Copper.

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[a] Reconnaissance in southwestern Alaska: Twentieth Ann. Rept. U. S. Geol. Survey, p. 263.

[b] Geology and Mineral Resources of a Portion of the Copper River District, by F. C. Schrader and Arthur C. Spencer; cited on previous pages.

[c] Op. cit.

[d] Reconnaissance from Resurrection Bay to Tanana: Twentieth Ann. Rept. U. S. Geol. Survey, Pt. VII, p. 324.

[e] Geology and Mineral Resources of a Portion of the Copper River District, by Schrader and Spencer; cited on previous pages.

SOUTHWESTERN ALASKA.

GENERAL STATEMENT.

As in southeastern Alaska, the workable coal beds are believed to be confined entirely to the Kenai formation, which has extensive development in this region. The rocks of this formation have been found near the head of Cook Inlet and at various localities to the southwest, nearly to the southern extremity of the Alaska Peninsula. They almost everywhere include lignitic seams, which at a number of localities are known to be workable. Rocks of this formation overlie the older metamorphic series unconformably. They are most often found as broad folds which are locally much faulted. As might be expected in a region of volcanic activity, the deformation of the rocks is of a local character. Volcanic rocks, both extrusive and intrusive, are often associated with coal-bearing beds. Spurr [a] has called attention to the fact that the higher Tertiary beds occurring about the Kenai also contain lignites of inferior quality. These younger beds can usually be distinguished from the Kenai by the fact that they consist of only slightly cemented or uncemented material. The coal in these beds is a brown lignite, which retains its woody fiber.

SUSHITNA RIVER.

The Kenai rocks on the Sushitna, which have been referred to, carry some coal, according to Eldridge. The outcrops of the Upper Sushitna coal-bearing rocks [b] occur along the main river above the Chulitna for 6 or 7 miles. The strata form bluffs 100 to 300 feet high and consist of clays and sandstone. The beds are undulating, dipping from 5° to 10°. There are 10 or 15 coal seams along this exposure, which are from 6 inches to 6 feet thick. Eldridge obtained no fossils, and according to his description these beds more nearly resemble the Upper Tertiary beds of the region, which carry the inferior coals, than those of the older Kenai formation. Eldridge also makes mention of some coal seams on the Upper Cantwell River, observed by him from a distance. Near the mouth of the Yentna he noted clays, sandstones, and conglomerates which carry small seams of lignite. Spurr[a] found the same rocks at the mouth of Hayes River, a tributary of the Skwentna, where they include seams of good lignite several feet thick.

On the western side of Cook Inlet near Tyonek, Eldridge [c] also found Kenai rocks, and reports concerning them as follows:

The extent of the Tyonek field was not investigated, but from independent reports by prospectors and Indians it is inferred that it extends for several miles inland, and

[a] Reconnaissance in southwestern Alaska: Twentieth Ann. Rept. U. S. Geol. Survey, Pt. VII, p. 262.

[b] A reconnaissance in the Sushitna Basin and adjacent territory, Alaska, by George H. Eldridge: Twentieth Ann. Rept. U. S. Geol. Survey, Pt. VII.

[c] Op. cit., p. 21.

from a point 7 or 8 miles west of Tyonek along the coast as far northward at least as Theodore River. From a point 2 miles west of Tyonek to one about 6 miles west there is a continuous outcrop of the Kenai formation—sandstones, shales, and coal seams—along the beach bluffs. The strata dip from 35° to 60° SE., the amount varying locally. The general strike of the series, NNE., would carry the strata to a point about 10 miles up the Chulitna, where, indeed, coal is reported in veins equaling in size and number those at the beach. Coal is also reported about 30 miles up the Beluga River, nearly in line with the Chulitna and Tyonek exposures. This would make an outcrop on the strike, beneath the superficial deposits of silt and gravel, of approximately 30 miles, with a width, as shown at the beach, of about 4 miles. The number of seams, large and small, exposed along the beach west of Tyonek is 36, but it is possible that some of them are repetitions by faulting, though no actual evidence to this effect was found. The beds vary in thickness from a foot to 15 feet, there being many from 4 to 6 feet thick. As a rule, not only is the coal[a] of low grade, but the seams are many times split by slate, clay, or sand partings. There are, however, three or four seams in which probably one or two 3-foot benches of moderately clean coal might be found.

Spurr regards these rocks as belonging to the younger Tertiary series, and not to the Kenai. He reports the coal to be a brown lignite of inferior quality.[b]

KENAI PENINSULA.

General description.—The western part of this peninsula is largely occupied by the coal-bearing rocks of the Kenai series, while in the eastern part the older metamorphic series prevail. The following description of this field is quoted from Dall:[c]

This region includes the area west of the Kenai Mountains and extending along the eastern side of Cook Inlet, between Kachemak Bay on the southwest and Turnagain Arm at the northeast. This area is more than 25 miles wide and over 80 miles long, thus covering at least 2,000 square miles. The land comes to the sea in steep bluffs, generally with only a narrow beach at their base. The height of the bluffs is greatest at Bluff Point, near the entrance to Kachemak Bay, where it reaches 1,800 feet within half a mile of the water. Thence northeastward the strata describe a series of gentle, enormously extended waves, plainly visible from vessels sailing by the coast. The height of the plateau grows gradually less; at Cape Kasilof the coal seams finally sink below the sea level, and on the south shore of Turnagain Arm the land rises less than 50 feet above the sea level. The upper surface is more or less undulating, cut by numerous streams which form narrow, deep valleys in the soft Tertiary rocks, and, according to native reports, sometimes rise in large, shallow lakes which receive the drainage from the glaciers of the Kenai range. Nearly all this area is heavily wooded with spruce and larch, mixed with poplar, alder, and willow along the water courses. Entrance to some of the larger streams may be had at high water, but the only harbor is at Kachemak Bay. The Kenai formation containing the coal probably underlies the entire area of the plateau, but again it is only at Kachemak Bay that the strata are elevated to their greatest height, and the lower and more densely consolidated coal seams are brought near the surface. * * *

If the indications of Wossnessenski are correct there would seem to be a succession of about four gentle folds from Port Graham to Cape Kasilof, a distance in a north-

[a] Compare table of analyses, this report, p. 549.
[b] A reconnaissance in southwestern Alaska: Twentieth Ann. Rept. U. S. Geol. Survey, Pt. VII, p. 262.
[c] Coal and lignite of Alaska: Seventeenth Ann. Rept. U. S. Geol. Survey, Pt. I, pp. 787-788.

erly direction of some 70 miles. The lignite beds crop out at many places along the western shore of this area. At Anchor Cape (Kasnatchin), the northern head of Kachemak (or, as it is sometimes called, Chugachik) Bay, the coal is under water, but rises northward with the flexure of the strata. * * *

At Cape Starichkof two parallel beds of coal are visible for a long distance. The lower one is about 112 feet above the beach and is separated by 9 to 12 feet of sand and clay from the upper coal bed, above which the bluff rises 40 to 70 feet higher. At Cape Nenilchik the upper bed covers about 18 feet of fine, yellow sand and is separated from the lower bed by about 20 feet of sand and clay.

Kachemak Bay.—This is a deep indentation on the western side of the peninsula. It is about 30 miles in length and affords a good harbor. On its shores are the most extensive developments of coal mining in Alaska. The town of Homer, which is the chief settlement on the bay, is situated on the north side near the sandspit. Dall[a] says that bold cliffs of Kenai conglomerates, sandstones, and shales rise directly from the water or from a narrow beach. These beds carry many seams of lignite; the largest was observed near Coal Point, and is about 7 feet thick, with some thin shale partings. The beds dip at a low angle to the north. The coal, which is lignite,[b] is bright and clear, and has a tendency to break into cubical fragments when dried, and resembles anthracite in appearance. On the south side of the bay the coal-bearing rocks occur in isolated patches.

According to Dall, the most westerly developments are near Homer, on what he calls the Bradley seams, which consist of an aggregation of coal and shale, having a thickness of 7 feet. The thickest vein of clear coal measures 18 inches. It is the lowest seam in the section, and appears to be more compact and glossier than those occurring at a higher horizon.

About five miles to the east of Homer some developments have been made on the Curtis seam, which Dall describes as follows:

The clear coal is here 4 feet 7 inches thick, with about 6 inches of iron-stained sandstone above it and a thick, adhesive, gray clay below. This seam would require timbering to avoid caving in, if worked to any extent. Above this are three other seams, separated by thick beds of clay or soft sandstone. One of these, the lower seam, is nearly 4 feet thick; the others are somewhat thinner. The strata are here nearly horizontal. The coal, though lighter than the Bradley, is fairly compact, with a dull fracture, no visible pyrite, occasional thin lenses of sand or shale, and a tendency to break up cubically.

To the east some prospecting has been done on coal veins exposed in McNeil and Cottonwood canyons. The most extensive developments up to the time of Dall's visit were made in Eastland Canyon, on the north side of the bay, about 10 miles northeast of Homer. He describes the locality as follows:[c]

A small tramway leads back several hundred yards into the canyon, and at a height of 270 feet above the tide we found a vein 2 feet 4 inches thick of clear coal, and associated with it alternate seams of coal and clay, or "bone," the total thickness of

[a] Op. cit., p. 789. [b] See table of analyses, this report, p. 549. [c] Op. cit., p. 793.

the series being 6 feet. The rocks here are nearly horizontal, and comprise sandstone, whitish clay containing large waterworn bowlders, shales, and lignite, the upper part covered with from 5 to 10 feet of reddish gravel. The bluffs attain a height of from 600 to 800 feet, the land behind them reaching 1,800 feet. These explorations were begun in December, 1894, by the North Pacific Mining and Transportation Company, under the supervision of Mr. Curtis. About 300 tons had been taken out and sent to San Francisco for trial, and another cargo was to be shipped shortly after our visit. Mr. Curtis had only a few men employed, and the work he was doing was of the nature of exploration. The development of the property, he stated, would depend upon the result of experiments with the coal.

In the last two years there has been considerable development of coal in the vicinity of Homer by the Cook Inlet Coal Fields Company. Buildings have been erected and 6 miles of railway constructed. In the report of the governor of Alaska for 1900,[a] the company is said to be developing coal veins which are from 2 to 7 feet thick, aggregating 150 feet in all.

KADIAK ISLANDS.

Evidence of the presence of coal has been found at a number of points on the islands, but no developments have been made. These coals occur in the coarse sandstones and conglomerates of the Kenai, which are evidently an extension of the same formation occurring on the peninsula of the same name to the north. Lignites[b] are reported from Sitkinak Island, from Red River, and from Ugak Bay on the eastern side of Kadiak Island.

AMALIK HARBOR.

This bay connects with Shelokof Strait, which separates Kadiak Island from the mainland. The coal veins[c] occur in coarse sandstones on the south side of the entrance to the harbor behind Takhli Island. The beds dip about 30° NE. In the lower beds of the sandstone, which is 250 feet thick, there are three seams of coal, each of which is about 18 inches thick. The coal is bituminous and of good quality. Its bituminous character may be due to the presence of a granite dike which cuts the sandstones in close proximity.

ALASKA PENINSULA.

The Kenai rocks are well distributed over the peninsula and are known to carry coal at several localities. Spurr[d] makes note of coal veins on the southeastern shore of the southeast one of the Ugashik lakes in the northern part of the peninsula. So far as determined this coal is of rather poor quality, but resembles cannel coal in appearance.

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[a] Page 58. [b] Dall, p. 800. [c] Dall, p. 799.

[d] A reconnaissance in southwestern Alaska: Twentieth Ann. Rept. U. S. Geol. Survey, Pt. VII, p. 262.

Coal has been mined for local use on the left bank of the Chignik River, about 15 miles from Chignik Bay. The country rock is Tertiary sandstone, which forms low bluffs along the river. Dall describes the occurrence as follows:[a]

The mine is directly on the bluff, on the left bank of the stream. The beds dip N. 25° E., and the strike is N. 15° to 20° W. The bedding is very regular on the whole, with a few small slips. The coal occurs in one small seam, about 16 inches in average thickness, of which 1 inch is a more or less regular streak of sandstone. Above this seam are about 11 inches of hard sandstone and 6 inches of coal. About 6 feet higher is a 6 or 8 inch seam, very adhesive to the roof, which is of a very firm sandstone. The coal is solid, clean, bright, with no visible pyrite or lime. The rocks are of a brownish sandstone, gray where not weathered. * * *

There are two 6-foot tunnels, about 40 feet apart and 240 feet long. * * *

The seam comes to the surface of the ground in a ravine about 30 feet above the upper tunnel, and has been traced inland more than half a mile.

At Coal Cape,[b] southwest of Chignik Bay, lignite beds outcrop, and lignites are reported from Coal Bay, from the neighborhood of Portage Bay, and from Pavloff Bay.

On the west side of the peninsula coal has been reported from only one locality, namely, at Herendeen Bay, where it has been mined, but so far without any great measure of success. The coal-bearing beds occupy an area lying between Port Möller and its southern arm, Herendeen Bay. The beds are of Kenai age,[c] but are intimately associated with Cretaceous rocks. According to Mr. Ernest G. Locke, who examined the region, the rocks associated with the coal consist of clays, shales, and heavy conglomerates. The largest vein is 4½ feet thick, and there are many smaller ones. The beds are said to be much folded and faulted, giving an irregularity to the coal veins which calls for careful mining methods. Mr. Locke informed the writer that the coal, which he describes as bituminous, is of excellent quality, is hard, clean, and breaks into large chunks, which will stand handling and weathering.

SHUMAGIN ISLANDS.

These islands lie adjacent to the southern coast of the Alaska Peninsula, in latitude 55°. Popoff and Unga islands, the westernmost of the group, contain considerable areas of Kenai rocks.[d] The same beds are represented along the western margin of Nagai Island and probably on Sannakh Island. The Kenai beds overlie an older metamorphic series.

Coal has been mined on Coal Bay, an indentation of the northern

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[a] Coal and lignite of Alaska: Seventeenth Ann. Rept. U. S. Geol. Survey, Pt. I, pp. 802–803.

[b] Dall, op. cit., p. 804.

[c] Dall, op. cit., pp. 806–807. Also Stanton's statement regarding fossils from this locality, this report, p. 528.

[d] Dall, op. cit., pp. 809–810.

shore of Unga Island, for many years. In this locality Dall notes the following section:

Section at Coal Bay, Unga Island.

	Feet.
Conglomerates and sandstones with a little sandy shale	200
Thin leaves of lignite aggregated into three series of 3 feet each, interstratified with beds of sand and gravel of variable thickness, with some pyrite. Total about	40
Soft sandstone and gravel, little indurated	150
Lignitic bands, not exceeding 8 inches, very pyritiferous, interstratified with sands and gravel	200
Clay ironstone with leaf impressions to beach	4

The best veins of coal are a foot thick. The coal is hard, clean, and black, and slacks on weathering into small cubical fragments. Dr. Dall's conclusion in regard to this coal is unfavorable. It is, however, convenient of access for steamers running to Dutch Harbor from Cook Inlet or Kadiak, and continues to be mined in a small way.

ALEUTIAN ISLANDS.

Dall[a] has described a number of localities in the Aleutian Islands from which coal has been reported, and also some in which fossil amber has been found. There seems to be no doubt that there are lignite-bearing Tertiary beds in the archipelago. It will remain for future investigations to determine whether or not these Tertiary beds belong to the older series, which carry commercial coals.

CHARACTER OF COALS OF SOUTHEASTERN AND SOUTHWESTERN ALASKA.

The coals of the southern part of the Territory vary in character from the brown lignites of the Tyonek fields to the bituminous and semianthracite of the Controller Bay region. The larger percentage of these coals, and practically all of those which have received any development, may be classed as lignites.

A number of proximate analyses[b] of these coals are grouped together in the table, page 549. For the sake of comparison the volatile matter and fixed carbon have been recalculated as percentages of the total fuel constituents.[c] The ratio between these two constituents, which gives an index of the fuel values of the coals, is given at the right of the table, and is called the fuel ratio.

[a] Op. cit., pp. 811–814.

[b] In all the analyses made by the Geological Survey, except two, the old methods were employed. By this method the volatile matter is determined by heating three and one-half minutes over Bunsen burner and three and one-half minutes over blast. Moisture was determined by heating one hour at 100° C., and the Eschka method of determining sulphur was employed. Two analyses, by Mr. Steiger, one from the Upper Koyukuk and one from a point 12 miles above Nulato, on the Yukon, were by methods recommended by "Committee on Coal Analysis." (Jour. Am. Chem. Ass., Vol. XXI, No. 12.)

[c] These calculations were made by Mr. George B. Richardson.

Analyses of coal from southeastern and southwestern Alaska.

Locality.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Character of coal.	Recalculated.		
							Fuel elements.		Fuel ratio.
							Volatile matter.	Fixed carbon.	
McCluskey seam, Kootznahoo, Admiralty Island[a]	2.44	44.75	47.93	4.88	0.67	Lignite (coking)	48.28	51.72	1.07
Sepphagen seam, Kootznahoo, Admiralty Island[b]	1.66	35.40	31.80	31.14	.32	....do	52.68	47.32	.90
Sullivan seam, Kootznahoo, Admiraly Island[c]	.82	21.86	35.52	41.80	.51	....do	38.10	61.90	1.62
Mitchell seam, Kootznahoo, Admiralty Island[d]	2.37	31.73	30.89	35.01	.17	Lignite	50.67	49.33	.97
De Groff seam, Kootznahoo, Admiralty Island[e]	2.57	55.44	29.75	12.24	.89	Lignite (coking)	65.08	34.92	.53
Chilkat River, near Controller Bay[f]	.77	13.79	82.36	3.08	....	Semianthracite (coking)	14.34	85.66	5.97
Controller Bay[g]	.75	13.25	82.40	3.60	....	....do	13.85	86.14	6.22
Icy Bay[h]	.78	13.22	80.30	5.70	....	Semianthracite	14.13	85.86	6.07
Tyonek, Cook Inlet[i]	9.07	49.41	30.84	10.68	....	Brown lignite (coking)	61.57	38.48	.62
Bradley seam, Cook Inlet[j]	12.64	43.36	37.14	6.86	.49	Lignite (coking)	53.94	46.06	.85
Eastland seam, Cook Inlet[j]	11.72	46.50	34.64	7.14	.40	....do	57.31	42.69	.74
Eastland[k]	10.35	52.22	34.58	2.85	.17	....do	60.16	39.84	.66
Eastland[k]	11.59	50.70	30.84	6.87	.22	....do	62.18	37.82	.61
Curtis seam, Cook Inlet[k]	11.67	52.37	21.01	14.95	.46	....do	71.37	28.63	.40
Fort Graham, Cook Inlet[l]	1.25	39.87	49.89	7.82	1.20	Lignite	44.42	55.58	1.25
Red River, Kadiak[m]	12.31	51.48	33.80	2.41	.17	Lignite (coking)	60.37	39.63	.65
Amalik Harbor, Alaska Peninsula[n]	1.62	36.56	52.92	8.90	.75	Semibituminous coal (coking).	40.86	59.14	1.44

[a] Coal and lignite of Alaska, by W. H. Dall: Seventeenth Ann. Rept. U. S. Geol. Survey, Pt. I, p. 782. Analysis by U. S. Geol. Survey.
[b] Dall, op. cit., p. 779. Analysis by U. S. Geol. Survey.
[c] Dall, op. cit., p. 780. Analysis by U. S. Geol. Survey.
[d] Dall, op. cit., p. 783. Analysis by U. S. Geol. Survey.
[e] Dall, op. cit., p. 781. Analysis by U. S. Geol. Survey.
[f] Geology and mineral resources of part of the Copper River Basin, by F. C. Schrader and Arthur C. Spencer, U. S. Geol. Survey, 1901. Analysis by U. S. Geol. Survey.
[g] Reconnaissance in southwestern Alaska, by J. E. Spurr: Twentieth Ann. Rept. U. S. Geol. Survey, Pt. VII, p. 263. Analysis furnished by Mr. F. H. Shepherd.
[h] Spurr, op. cit., p. 263. Analysis furnished by Mr. F. H. Shepherd.
[i] Reconnaissance in Sushitna Basin and adjacent territory, by G. H. Eldridge: Twentieth Ann. Rept. U. S. Geol. Survey, Pt. VII, p. 23. Analysis by U. S. Geol. Survey.
[j] Dall, op. cit., p. 795. Analysis by U. S. Geol. Survey.
[k] Dall, op. cit., p. 796. Analysis by U. S. Geol. Survey.
[l] Dall, op. cit., p. 797. Analysis by U. S. Geol. Survey.
[m] Dall, op. cit., p. 800. Analysis by U. S. Geol. Survey.
[n] Dall. op. cit., p. 799. Analysis by U. S. Geol. Survey.

Analyses of coal from southeastern and southwestern Alaska—Continued.

Locality.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Character of coal.	Recalculated. Fuel elements. Volatile matter.	Recalculated. Fuel elements. Fixed carbon.	Recalculated. Fuel ratio.
Chignik River, Alaska Peninsula [a]	1.89	41.47	48.46	8.18	1.71	Semibituminous coal (coking).	46.11	53.89	1.17
Unga, upper seam, Shumagin Islands [b]	11.26	40.51	41.24	6.99	2.17	Bright lignite (coking)	49.55	50.45	1.02
Unga, lower seam, Shumagin Islands [b]	10.58	66.21	15.26	7.95	.56	Dull lignite	81.27	18.73	.23
Herendeen Bay, Alaska Peninsula [c]	3.43	39.00	47.40	10.17	.44	Bituminous coal (noncoking).	45.14	54.86	1.21

[a] Dall, op. cit., p. 803. Analysis by U. S. Geol. Survey.
[b] Dall, op. cit., p. 810. Analysis by U. S. Geol. Survey.
[c] Dall, op. cit., p. 807. Analysis by U. S. Geol. Survey.

The comparisons of the moisture contents of the analyses given in this report are liable to be misleading, as there was in most cases no uniformity of methods employed in the collection and preservation of the samples. An exception to this are those collected by Dr. Dall, who says:[a]

These analyses are of coal taken from the seam and tied up in bags of stout duck, and analyzed immediately on arrival at headquarters. The moisture is probably about normal for coal treated in the ordinary way of commerce.

In the table on page 552 some average analyses of Pacific coast coals are compared with those of southern Alaska. This shows that the Cook Inlet lignites have a normal percentage of water; that the volatile matter is above and the fixed carbon below the average of the Pacific coast lignites. The same comparison showed 7.73 per cent of ash for Cook Inlet and 9.79 per cent for Pacific coast lignites. The average of five varieties of Cook Inlet coals gave 0.392 per cent of sulphur, and the average of fourteen Pacific coast lignites gave 1.71 per cent of sulphur. In their fuel ratios the average of the Pacific coast is decidedly better than of the Cook Inlet. The coals of Alaska Peninsula average somewhat better. The mean of five analyses gave a fuel ratio of 1.27 per cent compared with 1.17 of Pacific coast lignites and 1.20 for Vancouver Island coals. Unfortunately these better classes of coals have not yet been found in sufficient quantities to warrant mining operations on a large scale.

The best coals of the Territory are the seams of semianthracite found between Icy Bay and Controller Bay. The analyses of three of these coals (see table) show them to be far superior to any of the others, including the best of the British Columbia coals. Unfortunately it is not known whether the samples analyzed represent averages of the seams or were picked. The extent of these coal seams, and whether broken or undisturbed, have also not been determined.

[a] Coal and lignite of Alaska: Seventeenth Ann. Rept. U. S. Geol. Survey, Pt. I, p. 827.

Comparison of average analyses of Southern Alaska and British Columbia and Pacific coast coals.

	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Recalculated fuel element.		
					Volatile matter.	Fixed carbon.	Fuel ratio.
Average composition of 5 Cook Inlet lignites[a]	11.59	49.03	31.64	7.73	60.77	39.33	0.64
Average composition of 4 Alaska Peninsula coals[b]	2.05	39.23	49.92	8.77	44.132	55.84	1.27
Average composition of 34 Pacific coast lignites[c]	11.55	36.13	42.10	9.79	47.45	52.55	1.17
Average composition of 15 Vancouver Island coals chiefly from Nanaimo and Comax[d]	......	30.33	60.23	9.44	33.50	60.23	1.20
Average composition of 3 coals from the vicinity of Controller Bay[e]	.76	13.42	81.68	4.12	14.21	85.68	6.06

[a] Dall, op. cit., p. 828. [b] This report, see table pp. 549-550. [c] Dall, op. cit., p. 829.
[d] Mineral wealth of British Columbia, by G. M. Dawson: Geol. Nat. Hist. Survey Canada, new series, Vol. III, Pt. II, 1887-88, p. 92 R.
[e] This report, see table, pp. 549-550.

While chemical analysis helps to determine the fuel value of a coal, it is at best an incomplete test, and a final decision can be reached only by putting the coal to the actual use for which it is intended. Though the Alaskan coals have been used on local steamers and coasting vessels, very little accurate information is available regarding their fuel value. The Cook Inlet lignites and the Alaska Peninsula semibituminous coals have been considerably used, but the Controller Bay semianthracites, so far as known, have never been tested.

Dr. Dall collected some data in regard to tests made of southern Alaska coals, and the following is quoted from his report:[a]

Coal from the best of the Kootznahoo Inlet beds, which have been designated the McCluskey outcrop, was tried in steam launch No. 18 of the United States Coast and Geodetic Survey steamer *Patterson*, under coiled tubular boiler. According to the informal report of the engineer, it burned well and developed about three-fourths of the steaming value of the Wellington (B. C.) coal usually used. It was decidedly better than the Comax coal.

During part of the expedition of twenty-eight days' cruising on the steam tug *Kodat*, in July and August, 1895, we were obliged to burn coal from the Bradley seam, Kachemak Bay, Cook Inlet, which was dug out of the beach at low water with crowbars and burned as it was, covered more or less with barnacles and seaweed. This coal, being under water most of the time, must have had a larger percentage of moisture than the normal amount belonging to it. The opinion of the engineer of the *Kodat* was to the effect that this lignite did from 60 to 75 per cent of the duty of Wellington (B. C.) coal.

Several hundred tons of coal from Eastland Canyon, Kachemak Bay, were imported

[a] Op. cit., pp. 830, 831, and 832.

into San Francisco by the Alaska Mining and Transportation Company, in 1895, and distributed to various manufacturing establishments for trial. Among these was the foundry of Messrs. W. T. Garrat & Co., well known as the principal brass founders of the Pacific coast. I was informed by their manager that this coal, to the amount of 50 tons, had been in use for making steam in their establishment, and was regarded by them as a very fair article of steaming coal. When a good fire was kept up they used 2,600 pounds in a given time, during which they would have used 2,200 pounds of Comax (B. C.) coal. With a low fire and small pressure of steam the amount used was 2,240 pounds to 1,350 of Comax. They stated that if the Cook Inlet coal could be furnished at a price corresponding to its relative efficiency compared with the British Columbian coal they should be glad to make regular use of it.

By permission of the Secretary of the Navy, and at the request of some New York parties, Lieut. R. P. Schwerin, in April, 1891, proceeded to the Cook Inlet region to examine the coal fields. The party was provided with a diamond drill and examined numerous seams. From four localities in particular, one of which was the McNeil canyon, Kachemak Bay, 50 tons of coal each were mined and brought to San Francisco. Lieutenant Schwerin informed me that during the entire summer this coal was used under the boiler and for cooking in camp and aboard ship. It gave very satisfactory results for stationary purposes, though the coal slacks into chip-like fragments rather rapidly after exposure to a dry atmosphere. He induced the Southern Pacific Company of California to make a test of the coal on their locomotives, a purpose for which it proved unfit, owing to its sparking tendency, which under forced draft was very pronounced in spite of the use of fine netting over the stacks. There was no trouble of this kind when used under a stationary engine or in a cooking stove.

The following summary of the data of the test, prepared September 29, 1891, was kindly furnished to Dr. Becker by Lieutenant Schwerin, who is now one of the staff of the Southern Pacific Railway organization. The kinds of coal with which the Cook Inlet lignite was compared were the ordinary Nanaimo coal from Vancouver Island and bituminous Cardiff coal imported as ballast by wheat ships.

Comparative test of Cook Inlet, Nanaimo, and Cardiff coals.

	Cook Inlet.	Nanaimo.	Cardiff.
Number of trips	2	2	4
Average number of miles per trip	86	168	86
Average gallons water used per trip	3, 734	13, 836	2, 989
Average pounds fuel per trip	6, 982	18, 551	3, 601
Average number loaded cars per trip	6. 2	11. 98	6
Average number empty cars per trip	....	1. 401	.75
Average tons weight loaded cars per trip	155. 35	....	139
Average tons weight empty cars per trip	....	....	21. 25
Average tons weight train without the engine and tender	155. 35	301. 47	160. 25
Gallons water used per ton of train	24. 04	45. 895	18. 653
Pounds fuel used per ton of train	44. 94	61. 535	22. 473
Water evaporated per pound of fuel	4. 46	6. 215	6. 917
Fuel burned per gallon of water evaporated	1. 87	....	1. 205
Average steam pressure	130. 5	143	150. 3
Average temperature of air	....	....	52°

Comparative test of Cook Inlet, Nanaimo, and Cardiff coals—Continued.

	Cook Inlet.	Nanaimo.	Cardiff.
Average temperature of feed water	68°	....	57°
Average temperature of steam	355.6°	....	365.7°
Area of grate, in square feet	16.87	25.6	16.87
Average fuel per hour per square foot of grate, pounds	....	....	54.215
Total heating surface	1,325	1,288	1,325
Pounds fuel burned per hour per square foot of heating surface	....	....	.69
Pounds fuel burned per ton per mile	.5226	.3663	.2613
Equivalent evaporation from temperature of feed water	5.33	7.507	8.369
Average number of miles run per ton fuel burned	24.635	18.112	47.762
Per cent value of fuel from evaporation	63.678	89.7	100

It thus appears that the Cook Inlet coal, under these conditions, has 71 per cent of the heating effect of Nanaimo coal and 63.7 per cent of Cardiff bituminous, a result which agrees fairly well with that derived from the other tests above mentioned.

The Herendeen Bay coal has been tested in United States Fish Commission steamer *Albatross*, and the following report was submitted by C. R. Roelker, passed assistant engineer, United States Navy, in regard to it:[a]

The following statement regarding the coal received from the mine recently opened in Herendeen Bay is based on the results obtained with some 80 tons of this coal consumed while this vessel was engaged in her usual work at sea under average conditions.

The quantities of coal consumed and of refuse matter were carefully measured; the behavior of the coal in the furnaces was closely observed, and the results obtained have been deduced from the entries in the steam log.

The average consumption of the coal was at the rate of 25 pounds per square foot of grate per hour. The boilers furnished the same amount of steam as when we have been using a fair quality of Wellington coal, but to obtain this result we had to burn from 20 to 25 per cent more of the Herendeen Bay coal.

The coal ignites readily and burns with considerable flame, forming a loosely cohering coke, which easily breaks up into small pieces; thus a considerable amount of small particles of coal is lost through the grates. There was a large proportion of fine stuff in the coal, which burned well, but contained an excessive quantity of refuse matter.

The refuse amounted to 26 per cent of the total weight of fuel consumed; it consists of ash and cinders, no glassy clinker being formed. The smoke produced is lighter in color than that of Wellington coal and less soot is formed.

To form a correct estimate of the value of this coal for steaming purposes from the foregoing statement the following facts should be taken into consideration, viz, the coal received by us was the first lot taken from this newly opened mine; it came from one of the smaller veins through which a tunnel had been driven then 200 feet

[a] Bull. U. S. Fish Commission, Vol. IX, 1891, pp. 282-283.

in order to get access to the main veins; no proper facilities for screening the coal existed and in order to supply the quantity required by us a large amount of fine coal, containing much dirt, was delivered. It may be reasonably expected that as the mine becomes further developed and proper screening facilities are provided the amount of refuse matter in the coal will be greatly diminished and its steam-generating power correspondingly increased.

It will be, however, absolutely necessary to store this coal under shelter, as it appears to absorb moisture readily and the constant rains which have prevailed in this region during the present season would soon saturate it to such an extent as to greatly diminish its value as a fuel.

KUSKOKWIM REGION.

This region, embracing the basin of the Kuskokwim River and streams tributary to Bristol Bay, is not known to carry any workable seams, but small veins have been found at several localities. Spurr[a] states that the Cretaceous rocks on the Kuskokwim, below Kolmakof, are locally carbonaceous, and that Mr. Kilbuck, missionary at Bethel, found some small lignite seams there. In the same report reference is made to the occurrence of coal on Nunivak Island and Kaluyak Point. At the former place the seams are of brown coal, and one tested by Kilbuck was found to be very good for common use. The coal from Kaluyak Point, according to Kilbuck, occurs in a seam from 1½ to 2½ feet thick. This coal, which is lignite, has also been tested at Bethel and found to be good.

YUKON BASIN.

GENERAL STATEMENT.

The workable coals of the Yukon Basin, so far as determined, all occur in beds of Tertiary and Cretaceous age. In some parts of the basin carbonaceous beds have been found in strata of Paleozoic age, but these seem to have little or no fuel value. The writer[b] has described some impure coal seams occurring at the head of White River, which are probably of Carboniferous age.

Regarding the distribution of the coal-bearing strata in the Yukon district, our information is very incomplete. Coals are known to occur at a great many localities, but the horizons in which they are found have often not been determined and have seldom been traced away from the main waterways. A study of the various reports referring to the Yukon Basin has convinced the writer that it is at present impossible to differentiate the coal-bearing horizons, and on the accompanying map they are all grouped together. Spurr, in his study of the gold districts, incidentally mapped a number of different formations

[a] A reconnaissance in southwestern Alaska: Twentieth Ann. Rept. U. S. Geol. Survey, Pt. VII, p. 262.

[b] A reconnaissance from Pyramid Harbor to Eagle City, Alaska: Twenty-first Ann. Rept. U. S. Geol. Survey, Pt. II, p. 382.

which carried coal, but these subdivisions, because of lack of data, can not be carried to adjacent areas.

The oldest beds which carry coal, as has been shown, are probably of Cretaceous age, and occur in what Spurr named the "Mission Creek series." This series overlies the older metamorphic rocks unconformably. Spurr[a] describes this rock as black, calcareous, or feldspathic shale which alternates with thin beds of impure limestone and with beds of gray sandstone. These beds are generally considerably and sometimes intensely folded; are sometimes slightly sheared and altered, but are ordinarily fresh and recent in appearance. Cretaceous rocks are widely distributed in the basin.

The workable coals of Tertiary age occur in the Kenai series, which has the same character as in southwestern Alaska. These coals are all lignites (compare table of analyses, p. 565). In the discussion of the geologic relations mention has been made of some younger Tertiary beds of Miocene of Pliocene age which carry lignites. These latter probably have no commercial importance. The Kenai has been identified at various points along the Yukon between Dawson and the mouth of the river.

LOWER YUKON.

Coal has been reported from the vicinity of Anvik. The locality is said to be away from the main river. No details are available regarding this locality. A coal opening, developed by W. E. Williams,[b] has been described as being located on the north bank of the Yukon, about 60 miles above Anvik, but no further data are available.

Governor John G. Brady informed the writer that in the summer of 1900 some coal was being taken out of the Clemens Thein[b] mine, which is situated on the right bank about 90 miles below Nulato. Governor Brady stated that the vein was about 2 feet thick, and that a test of the coal seemed to show that it possessed good steaming qualities.

NULATO.

Near Nulato several coal openings have been made. Schrader[c] has made mention of the Pickett mine, about 10 miles above Nulato. The coal is a lignite, but is compact and is said to be a good steaming coal. The vein is about 30 inches thick. The coal is very fine after slaking in the air. The Blatchford mine, about 9 miles below Nulato, has produced some coal. The occurrence is probably similar to that at the Pickett mine, but no descriptions were obtained. The horizon of the coals in the vicinity of Nulato and below has not been definitely determined.

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[a] Geology of the Yukon gold district: Eighteenth Ann. Rept. U. S. Geol. Survey, Pt. III, p. 175.

[b] The positions of the mines are only approximately located on the accompanying map.

[c] A reconnaissance along Chandlar and Koyukuk rivers: Twenty-first Ann. Rept. U. S. Geol. Survey, Pt. II, p. 486.

KOYUKUK RIVER.

Schrader also found coal, probably of Tertiary age, on the Upper Koyukuk. He makes mention[a] of one coal vein near Tramway Bar where the lignite is about 12 feet in thickness, of which 9 feet is comparatively pure coal but is of inferior quality (compare table of analyses, p. 565). He also makes mention of lignitic fragments in the gravels of Chandlar River.

PALISADES.

Mr. H. N. Wood, assistant engineer, Revenue-Cutter Service, in a personal letter to the writer, makes the following statement:

> About 60 miles below the Tanana, just above the bluff known as the Palisades, is a vein claimed to be 20 feet thick. A prospecting tunnel has been dug, but no coal has been taken out for the use of steamers that I am aware of.

Spurr,[b] in his description of the geology of the vicinity, considers the beds to be of Miocene or Pliocene age. This fact would suggest that these coal seams belong to the Upper Tertiary, which usually carry inferior coals.

RAMPART REGION.

A number of coal veins have been found in the Lower Rampart region of the Yukon, chiefly in the neighborhood of Minook and Hess Creek. These are lignites occurring in the sandstones and conglomerates of the Kenai formation. The following is quoted from Spurr:[c]

> On the right-hand side of the Yukon, just below the mouth of Whymper River (or Hess Creek) there are exposed frequent seams of rather impure, lignitic coal which occurs in the shales of the Kenai series. These shales alternate with conglomerates, grits, and impure limestones. On this bluff three distinct seams have been opened by Oliver Miller, a noted Alaskan prospector. One of these seams is 2 feet thick, with two or three clay partings; another, in which a tunnel 40 feet in length has been driven, shows 3 or 4 feet of mixed coal and coaly shale, and then a seam of clear coal 18 inches thick. This coal is generally brittle, and contains amber like that of Coal Creek and vicinity. Next it is a bed of yellow and red clay, and then comes again carbonaceous shale, passing into green sandstone and conglomerates. All these beds are nearly vertical, and are even slightly overturned, the folding being well shown in the steep bluff.

The Drew mine, as nearly as can be determined, is at this locality described by Spurr. This is the most important of the Alaskan-Yukon mines and has produced considerable coal. A shaft 75 feet deep has been sunk, which is cribbed and housed and equipped with steam hoisting gear. Bunkers of 80 tons capacity are conveniently situated, with chutes to reach the decks of steamers moored at the bank. Another location in this vicinity is the Pioneer mine, situated

[a] Op. cit., p. 485.
[b] Geology of the Yukon Basin: Eighteenth Ann. Rept. U. S. Geol. Survey, Pt. III, pp. 199–200.
[c] Geology of the Yukon gold district: Eighteenth Ann. Rept. U. S. Geol. Survey, Pt. III, p. 381.

about 30 miles above Rampart. This mine is said to have produced considerable coal in 1900. A 4-foot vein of coal, which has been prospected, is located on Minook Creek, about 4 miles from Rampart City.

DALL RIVER.

Mr. Walter C. Mendenhall has kindly furnished the following notes on the occurrence of coal on the Dall River, a westerly tributary of the Yukon:

> One mile above the mouth of a small stream entering Dall River about 70 miles above its mouth a seam of lignitic coal, measuring approximately 11 feet in thickness, outcrops. The lignite and the associated gray and black shales have been extensively folded and now dip at an angle of 45° to the southeast. The lower half of the outcrop is a firm, clean, bright lignite, light in weight and resisting weathering fairly well, but the upper portion contains streaks of clay and bone, making it worthless as a fuel. The 4 or 5 feet at the base of the exposure compares well in appearance with other Alaskan lignites, and doubtless is a fuel of good quality.

BIG BLACK RIVER.

This is an easterly tributary of the Porcupine, which it joins about 20 miles above Fort Yukon. Coal has been reported from this stream,[a] but no details are known regarding its occurrence. It seems probable that it is a northerly extension of the same series that carries coal on the Yukon near the international boundary.

ALASKA EXPLORATION COMPANY MINE.[b]

This is said to be located 60 miles above Circle City. Up to 1900 only development work had been done. The vein is said to be 7 feet thick, and analysis shows it to be a lignite of good quality. It probably occurs in Kenai sandstone, though the horizon may be Cretaceous.

MISSION CREEK.

On the lower reaches of this stream and of its tributary, American Creek, there is a considerable development of Cretaceous rocks, which often carry lignites. As far as known, no attempts have been made to mine these coals.

FORTYMILE RIVER.

Toward the headwaters of the west fork of Fortymile fragments of lignite are common in the stream gravels. This lignite is probably associated with beds of Cretaceous age. Its distance from water transportation precludes its having any immediate value.[c]

[a] Reconnaissance of the Yukon gold district: Eighteenth Ann. Rept. U. S. Geol. Survey, Pt. III, p. 381.

[b] The position of this mine is only approximately indicated on the accompanying map.

[c] Reconnaissance from Pyramid Harbor to Eagle City, Alaska: Twenty-first Ann. Rept. U. S. Geol. Survey, Pt. II, p. 383.

BRITISH NORTHWEST TERRITORY.

The most extensive developments of the Yukon coals are on the Canadian side of the international boundary. The Alaska Exploration Company has done considerable systematic mining on Coal Creek, a tributary of Rock Creek, which flows into the Klondike. This mine is about 25 miles distant from Dawson. According to McConnell,[a] the coal is a lignite and the seams are locally disturbed. The lignite is hard and compact and shows no trace of woody fiber. There are two seams separated by a clay layer with clay roof and floor. The upper seam has a thickness of 3 feet; the lower, from 2 to 3 feet.

A coal mine has been opened by the North American Trading and Transportation Company on Cliff Creek,[b] 55 miles below Dawson, near the Yukon River. McConnell describes two lignite zones, consisting of alternating beds of clay and carbonaceous shales. The upper contains about 11 feet of coal in a section of about 16 feet, consisting of coal and clay partings. The lower contains two lignitic seams, 2 and 9 feet thick, and separated by 24 feet of clay. McConnell also makes mention of the discovery[c] of anthracite coal near the White Horse Rapids. Coal has long been known to occur in the Cretaceous rocks on the Lewes River,[d] 5½ miles above Rink Rapid, where there are several veins, the lowest of which is about 3 feet thick. A good many years ago a short drift was put into this vein. More recently a mine has been opened up which now furnishes coal for the river steamers.

In a letter dated Dawson, March 24, 1901, F. C. Schrader has given the writer the following description of an occurrence of coal on the Nordenskiold River, which joins the Lewes River a few miles above Five Finger Rapids:

> About 18 miles above its mouth occur coal beds, some 6 or 7 feet in thickness, and of fair grade. The associated rocks are bluish grits and sandstones, which are probably Cretaceous. The dip, which is to the northwest, averages 50°. The coal outcrops on both sides of the valley at points several miles apart. The locality where some development has been done is known as Porter's coal mine. Fossil plants are said to occur in this locality.

NORTHWESTERN ALASKA.

GENERAL STATEMENT.

Very little is known of the geology and mineral resources of this region except of the southern half of the Seward Peninsula, which has been studied in some detail. The coals of this region are, so far as known, of Tertiary and Cretaceous age. Tertiary rocks have been

[a] A summary report of the geological survey department for the year 1900, Ottawa, No. 26, p. 45.

[b] McConnell, op. cit., p. 46.

[c] Op. cit., p. 48.

[d] Exploration in the Yukon district and British Columbia, by G. M. Dawson: Rept. Geol. Survey Canada, new series, Vol. III, Pt. I, 1887-88, p. 148 B.

found near the eastern shore of Norton Bay,[a] and probably have extensive development to the east, while at Cape Lisburne[b] Cretaceous beds are known to occur, and what are probably Tertiary beds on the Kowak River. Outside of these three areas we have no absolute knowledge of the presence of rocks of Tertiary or Cretaceous age.

ULULUK CREEK.

Dall[c] makes mention of lignitic beds on Ulukuk Creek, a branch of the Unalaklik River. The beds, consisting of sandstones and argillites, dip 25° to 55° to the northwest. Capt. D. H. Jarvis informed the writer that some very good looking coal had been found near Unalaklik Cape, near the eastern shore of Norton Sound. These probably belong in the same series described by Dall.

SEWARD PENINSULA.

The country rock of the southern half of this peninsula is mostly of a metamorphic and igneous character and does not carry coal. In the eastern part of this area, however, Mendenhall[d] found some beds which he assigned to the Tertiary, and he saw some indications of the presence of coal, which he describes as follows:

> The only rocks encountered in the reconnaissance likely to carry coal are the sediments supposed to be of Tertiary age outcropping on the Tubutulik and Koyuk rivers in narrow belts. No direct evidence of the presence of this mineral was secured on the Koyuk, but along the river bank, associated with the sandstone outcrops on the Tubutulik, are numbers of small pieces of bright compact coal, seemingly of good quality. Some time would have to be spent in careful prospecting to determine the extent and value of the deposit.

KOWAK RIVER.

Lignites have been reported from the Kowak River which are said to be associated with sandstones and conglomerates. Lieut. John C. Cantwell[e] was the first to note this coal, and it has since been visited by prospectors. The following is quoted from his report:

> The coal is intimately mixed with a fine white clay, which renders its use for a small furnace almost impossible. However, it is my opinion, based on the experience of others, that the seams if worked would produce a good quality of coal.
>
> I saw numerous specimens of extra good bituminous coal which the Indians claim could be easily obtained on some of the small tributaries of the Kowak, but I never succeeded, although I tried several times, to definitely locate the place where such coal could be obtained.

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[a] Correlation Papers, Neocene, by W. H. Dall: Bull. U. S. Geol. Survey No. 84, p. 246.
[b] Report on coal and lignite of Alaska: Seventeenth Ann. Rept. U. S. Geol. Survey, Pt. III, p. 820.
[c] Bull. U. S. Geol. Survey No. 84, p. 248.
[d] Report on the Norton Bay region; U. S. Geol. Survey, 1901.
[e] Report of the cruise of the revenue-marine steamer *Corwin* in the Arctic Ocean in the year 1884, p. 56. Report of the cruise of the revenue-cutter *Corwin* in the Arctic Ocean, 1885, p. 48.

Lieutenant Stoney makes the following reference to coal on the Kowak, which he calls the Putnam River:[a]

On my second trip to the Putnam [Kowak] I discovered a vein of bituminous coal outcropping on the north side of the river about 90 miles from the mouth. I tried a lot of it in the furnace of the steam launch with very satisfactory results, though it had long been exposed to the weather. The vein was between 2 and 3 feet thick and dipped at an angle of 30° from the river. I think that a good quality of coal will be found farther in the bank.

Since the above was written, Mr. Walter C. Mendenhall has made a geologic reconnaissance of the Kowak River, and he has kindly furnished the writer with the following notes on the coal:

A short distance below the mouth of Reed River, on the north bank of the Kowak, a succession of beds of conglomerate, composed of pebbles of quartz, mica-schist, limestone, and serpentine, in a matrix containing much mica-schist, is exposed. The single conglomerate beds vary in thickness from 10 to 200 feet, but are uniform in character. Softer beds are associated with them, but are poorly exposed. These are sandstones, shales, fire clays, and lignites. A half dozen beds of the latter are indicated, but those sufficiently well exposed to measure are thin, not over 6 or 8 inches. One or two others may be 2 to 3 feet thick, to judge from the rather extensive bloom. The lignite examined is dirty with many shale partings, and the weathered fragments gathered burned rather slowly, but without heavy smoke. Rather offensive gases were given off, as is usually the case with low-grade lignites. The deposit is not economically important.

CAPE LISBURNE.

This cape is the northern promontory of a land mass projecting into the Arctic Ocean in about latitude 69°, and is about halfway between Cape Prince of Wales and Point Barrow. Coal was reported to occur in the vicinity of Cape Lisburne by Kellett[b] and other English explorers in the middle of the century. In 1879 Captain Hooper mined some coal for his vessel from a vein in this vicinity which was discovered the preceding year by Capt. E. E. Smith.[c] Since that time veins have been spasmodically worked for use of the revenue vessels and whalers. No systematic development was carried on, but when a vessel ran short of fuel a landing was made and the seamen were put to work digging out the coal at the most convenient place. One locality where mining was thus carried on has been called the Corwin mine; another the Thetis mine.

The geology of the Lisburne region has not been studied, though there are some random notes regarding it by various observers. The cape itself, which is about 800 feet high, is said to be made up of limestone,[d] which extends southward for some 40 or 50 miles. The

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[a] Naval Explorations in Alaska, by Lieut. George M. Stoney, United States Navy; United States Naval Institute, Annapolis, Md., 1900. p. 80.

[b] Alaska: Its Population, Industries, and Resources, by Ivan Petroff, Eleventh Census, p. 2.

[c] Report of the cruise of the United States revenue steamer *Corwin* in the Arctic Ocean. Capt. C. L. Hooper, U. S. R. M. S., Washington, 1880, pp. 30 and 32.

[d] Coal deposits of Alaska, by Winthrop Packard: The Colliery Guardian, Nov. 30, 1900, Quoted from New York Evening Post. Date not given.

strike of the rocks is probably in a general northeasterly and southwesterly direction, though no direct statement regarding it has been found in the literature. The coal seams, which are very numerous, are reported to be 6 inches to 40 feet in thickness. They are exposed in cliffs [a] facing the sea.

The rocks associated with the coal seams are sandstones [b] and conglomerates which are assigned to the Cretaceous. [c] The coal-bearing series is said to extend from near Cape Lisburne [d] to Cape Beaufort, the most promising veins lying in about the center of this segment of the coast. The coal from the Corwin coal mine is semibituminous, [b] burning with little smoke, kindling readily, and leaving a fine white ash. It has been found to be a good steaming coal.

During the summer of 1900 the Corwin Trading Company inaugurated a systematic development of this coal field. Some of the coal was shipped to Nome, where it found a ready sale. The district unfortunately lacks a good harbor, and the vessels in taking on coal have protection only from southerly and easterly storms, unless an offshore ice pack furnishes a lee.

In connection with these deposits it is interesting to note that Lieut. L. O. Howard [e] reports the finding of coal on the Colville River, near latitude 69°. As the strike seems to run in an easterly and westerly direction, this discovery suggests that the coal-bearing rocks of Cape Lisburne may extend inland.

Since the above was written Mr. F. C. Schrader, of the United States Geological Survey, has visited this locality. Mr. Schrader has kindly furnished the writer with the following notes in advance of the publication of his report:

> This coal occurs approximately 30 miles east of Cape Lisburne, where it seems to have been long known to the whaling vessels, which have occasionally made use of it when in need of fuel in the Arctic regions. It seems to be a bituminous coal, occurring in slate and sandstone of probably Mesozoic age, or older. The occurrence of the coal, so far as observed in the locality, is in eight or ten veins, varying from 1 to 16 feet in thickness, and all apparently persistent. They are all exposed within a distance of about three-eighths of a mile along the coast, which here cuts them diagonally, forming a generally steep-faced bluff, which rises from 30 feet high on the west to more than 100 feet above tide on the east. The veins dip southwestward at an angle of approximately 35°.
>
> The coal is of fair grade, and nearly all the veins are comparatively pure. Though some folding, slight faulting, and jointing has taken place in the region, the coal has not suffered much from crustal disturbance.
>
> The property, so far as known, has all been staked, mostly by the Arctic Development Company of San Francisco, which has been operating on the ground during the last season—1901—and has been disposing of the coal in the Nome market, where it

[a] See drawing by Captain Hooper in report cited, p. 30.
[b] Packard, op. cit.
[c] See page 530 of this report.
[d] Population and Resources of Alaska, by Henry D. Woolf, Eleventh Census, pp. 132–133.
[e] Naval Explorations in Alaska, p. 69; United States Naval Institute, Annapolis, Md., 1901.

is said to readily command $18 to $20 per ton in competition with Comox or United States coal at $25 per ton. The coal is said to be a good article for house use, but is not so satisfactory for steaming purposes on the ocean, owing to its too light specific gravity for the high-draft steamer furnaces.

There are no harbor facilities in the region of the mines, but the beach is open, exposed, and shallow, and susceptible to heavy surfs, much the same as at Nome, so that ocean vessels do not approach nearer than three-eighths of a mile to the shore. Loading at the present date is accomplished by lighterage, as at Nome.

KOK RIVER.

This stream flows into Wainwright Inlet,[a] which is a minor indentation of the Arctic coast, in about latitude 71°. In 1889 Henry D. Woolfe[b] found extensive deposits of lignite on the banks of the Kok River, not far from the sea. He claims that it is a hard lignite which burns well and leaves but little ash. It could be brought to the coast by light-draft barges.

Mr. F. C. Schrader has kindly furnished the writer with the following notes on the coals of the Arctic and Koyukuk regions from his unpublished manuscript:

> On the upper John River, a northerly tributary of the Koyukuk River, in approximately latitude 67° 7′ N. and longitude 152° W, considerable coal detritus was observed. This was of such quantity and character as to suggest the occurrence of bituminous coals of economic value somewhere in the region north of this locality and in the drainage basin of the John River. The remoteness of its location would make it valuable only for local consumption.
>
> Lignitic coal was also found in the region of the mouth of the Anaktoobuk River, a tributary of the Goobie or Colville River. This locality is about 70 miles from the coast, the latitude and longitude being approximately 69° 32′ N. and 150° 55′ W.
>
> The coal, which is a good grade of lignite, occurs in several seams 1 to 3 feet or more in thickness. The beds are nearly horizontal or dip very gently to the north and are well exposed for several miles along the river. They are probably Tertiary and form part of a series which goes to make up the Arctic coastal plain in this region. They are exposed in bluffs rising to a height of 200 feet above the river. The associated beds are mud rock, soft sandstone, impure limestone, and intermediate rock types. The coal occurs for the most part between the base and the middle of the section. It is a good grade of lignite and was used satisfactorily in camp fire, yielding a strong and lasting heat. Should there be a demand for coal on this part of the Arctic coast it might prove of economic value, the gradient and volume of the river being such that at high water it could be brought to the coast by river steamers.

CHARACTER OF COALS OF YUKON BASIN AND NORTHWESTERN ALASKA.

The table of analyses on page 565 shows the coals of this part of the Territory to be chiefly lignites, except those of Cape Lisburne, which are semi-bituminous. In their fuel values, as far as can be determined by analyses, they average much better than the Cook Inlet coals and not

[a] This inlet is just north of the limits of the accompanying map, Pl. XXXV.
[b] Population and Resources of Alaska, Eleventh Census, 1893, p. 133.

much below those of British Columbia. The use of the Yukon coals has been confined entirely to river steamers and to domestic purposes along the river. Not much information is obtainable in regard to their use on the river steamers, but they are usually said to be inferior to the Comox and Nanaimo coals. So far as known, they are never used alone, but are always mixed with the imported coals or with wood.

The writer is fortunate in being able to present the opinion of Mr. H. N. Wood, assistant engineer, United States Revenue-Cutter Service, on this subject. Mr. Wood was attached for two years to the United States steamer *Nunivak* while she was patrolling the Yukon River. The following is quoted from a personal letter, dated February 24, 1901:

My experience with Yukon coal was limited to a trial of the coal of but one of the Yukon River mines. This was that from the one known as Drew's mine, which is located on the bank of the Yukon directly opposite the mouth of Hess Creek. An attempt was made to steam the boilers of the United States steamer *Nunivak* using this coal alone, but without success. Used mixed with Comox coal in the proportion of two parts of Yukon to one part Comox, moderate steaming could be done. Used with wood it served fairly well, about 400 pounds being used with one cord of wood. Used to maintain low-banked fires when the engine was stopped, it seemed to be fully as good as Comox coal. If, however, a fire was wanted to furnish steam for running a 10-kilowatt dynamo, the Yukon coal was inferior, due chiefly to the waste caused by the shifting of the coal through the grates when the fires were disturbed with fresh coal or fire tools. Although the attempt to steam with this coal was a failure, I am of the opinion that with some experimenting to determine the best kind of grates, amount of grate surface and draft most suitable, and the proper way to handle the coal in the furnace, good results could be obtained. Judging by my limited experience, the Yukon coal will compare with Comox coal and with wood about as follows, using the average hourly consumption of the *Nunivak* as a basis: 1,200 to 1,500 pounds Comox coal=2,000 to 2,500 pounds of Yukon coal=1¼ to 1½ cords of spruce wood. Comox coal was on the market in St. Michael in 1899 at $15 per long ton. The same price was charged per short ton for the Yukon coal at the mine. The cost of wood is from $6 to $10 per cord.

As far as I was able to learn, through inquiries of captains and engineers on river steamers, there are no vessels that have ever successfully used the native coal alone. It is used chiefly mixed with wood, sometimes with outside coal. The quality of the coal from the various mines of the Lower Yukon is said to vary but little. That from the mine of the upper river, in British territory, is claimed to be somewhat better. The general opinion of river engineers of the Yukon coals is decidedly unfavorable.

I was told by a man who served on the *Nunivak* in the capacity of chief oiler that the quality of Yukon coals was very much like that of the coal obtained at Coal Bay, in Cook Inlet. This man had served on a vessel on the coast that made a trial of the Cook Inlet coal.

The Cape Lisburne coals are, from all reports, decidedly the best coals which are known to occur in any considerable quantity in Alaska. They have been successfully used on whaling vessels and on revenue cutters, and during the summer of 1900 were used at Nome for domestic and steaming purposes. Coal is known to occur in this northern region in considerable quantities, but it will remain for future investigations to determine whether it is all of as high grade as the samples which have been analyzed and tested. The writer is indebted to

Analyses of coals of Yukon Basin and northwestern Alaska.

	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Character of coal.	Recalculated. Fuel elements. Volatile matter.	Recalculated. Fuel elements. Fixed carbon.	Recalculated. Fuel ratio.
Lewes River, 5½ miles above Rink Rapid[a]	6.03	36.92	49.03	8.02	....	Lignitic coal	42.95	57.05	1.33
Cliff Creek, upper working, Yukon River[b]	8.57	42.04	45.77	3.62	....	Lignite (coking)	47.87	52.13	1.08
Cliff Creek, lower working, Yukon River[b]	10.58	40.10	46.74	2.58	....	.....do	46.17	53.83	1.16
West of Dugdale on White Pass Railway[b]	2.31	5.59	67.20	24.90	....	Anthracite (coking)	7.67	92.33	12.03
Coal Creek, upper seam, Yukon River[c]	18.31	34.96	40.88	5.85	....	Lignite (coking)	46.09	53.91	1.17
Coal Creek, lower seam, Yukon River[c]	19.37	33.85	37.45	9.33	....	.....do	47.47	52.53	1.11
Cliff Creek, Yukon River[d]	18.0	44.3	33.6	3.1	0.82	Lignite	56.87	43.13	0.75
Do.[d]	16.0	35.5	38.5	10.0	Trace.	.....do	47.97	52.03	1.08
Do.[d]	16.6	42.9	25.5	15.0	....	.....do	62.71	37.29	0.59
Do.[d]	12.5	37.5	34.6	15.4	....	.....do	52.01	47.99	0.92
Do.[d]	9.98	44.08	40.99	4.95	2.37	.....do	51.82	48.18	0.93
American Creek, Yukon River[e]	6.75	39.13	37.59	16.53	3.40	Lignite (noncoking)	51.01	48.99	0.96
Left bank of Yukon, 60 miles above Circle City[f]	7.7	29.8	51.8	9.4	1.0	.....do	36.52	63.48	1.73
Small creek emptying into Yukon below Coal Creek[g]	6.24	43.94	47.74	2.08	....	Hard lignite	47.93	52.07	1.08
Miller's mine nearly opposite mouth of Hess Creek, Yukon River[g]	7.29	37.38	36.91	18.42	....	.....do	50.32	49.68	0.98
Upper Koyukuk[h]	4.47	34.32	48.26	12.95	....	Brown lignite (noncoking)	41.55	58.45	1.40
Twelve miles above Nulato on the Yukon[h]	0.86	25.75	66.51	6.88	....	Semibituminous (coking)	27.92	72.08	2.22
Cape Lisburne[i]	3.75	43.75	47.39	5.11	.360	Semibituminous (noncoking)	48.00	52.00	1.08

[a] Exploration in the Yukon district and British Columbia by George M. Dawson: Geol. Survey Canada, 1887–88, new series, Vol. III, Pt. I, p. 149 B. Analysis by G. C. Hoffman, Geol. Survey Canada.

[b] R. G. McConnell, Summary report for 1901, Geol. Survey Canada, p. 48. Analysis by Geol. Survey Canada.

[c] McConnell; op. cit., p. 46. Analysis by Geol. Survey Canada.

[d] North American Trading and Transportation Company.

[e] Maps and descriptions of Alaska, by E. C. Barnard, U. S. Geol. Survey, 1898, p. 81. Analysis by U. S. Geol. Survey.

[f] Alaska Exploration Company. Analysis by G. Beraud.

[g] Geology of the Yukon gold district, by J. E. Spurr: Eighteenth Ann. Rept. U. S. Geol. Survey, Pt. III, p. 382. Analysis by H. N. Stokes, U. S. Geol. Survey.

[h] Reconnaissance along Chandlar and Koyukuk rivers, Alaska, by F. C. Schrader: Twenty-first Ann. Rept. U. S. Geol. Survey, Pt. II, pp. 485–486. Analysis (not published) by George Steiger, U. S. Geol. Survey.

Corwin Trading Company. Analysis by Albert H. Welles.

Mr. George O. Fogg, secretary of Corwin Trading Company, for the following reports on the quality of this Cape Lisburne coal:

Analysis of sample of Alaskan coal.

[Analyst, Albert H. Welles.]

	Per cent.
Moisture	3.75
Volatile matter	43.75
Fixed carbon	47.39
Ash	5.11
Total	100.00
Sulphur	0.36

Color of ash, light brown.
The coal is of very good quality in every way.

Mr. Charles L. Norton, of the Massachusetts Institute of Technology, made the following report to the Corwin Trading Company on Cape Lisburne coal:

I find that the specimens of Alaska coal which you recently sent me have a calorific power of 7,560 calories per gram, or 13,600 B. T. U. per pound. This is quite as good as the average western coal, and is not more than 10 per cent inferior to the best eastern coals. I can not guarantee the sampling of the coal, as I have had only a few small sample lots to work from. To guarantee the same I should have to select samples from several tons. I have made 28 combustions of the samples you sent me, and the figure given below is the average value.

Comparative values:

New River	14,200 B. T. U.
Alaska Corwin	13,600 B. T. U.

DEVELOPMENT OF COALS.

Some of the early explorers report the presence of coal in what is now the territory of Alaska, but during the first century of Russian occupation no attempt seems to have been made to exploit it. In 1852 operations were inaugurated by the Russian American Company to open coal mines at Port Graham[a] on the western side of Kenai Peninsula. This was probably the first mining done in Alaska, and the Russians soon abandoned it, but induced an American company to develop coal mines at Port Chatham. These mining operations were continued for about ten years,[b] and supplied the Russian company's steamers. With the development of the British Columbia, Puget Sound, and other Pacific coal fields the enterprise became unprofitable, and was abandoned when the Territory was transferred to the United States.

In 1868[c] Commander Mitchell, United States Navy, visited Kootznahoo Inlet, Admiralty Island, in the United States steamship *Saginaw*,

[a] Alaska: Its Population, Industry and Resources, by Ivan Petroff, Tenth Census, p. 115.
[b] Coal and lignite of Alaska: Seventeenth Ann. Rept. U. S. Geol. Survey, p. 786.
[c] Dall, op. cit., p. 777.

to find the coal which had been reported by a native at Sitka. He mined a few tons, and the following year Capt. J. R. Meade, who had succeeded to the command of the *Saginaw*, secured some 30 to 50 tons at this locality which had been mined by contract with natives.

In 1868 Capt. J. W. White, of the United States Revenue steamer *Wayanda*, reported coal near Point Gardiner, at the southern extremity of Admiralty Island, and some years later[a] an unsuccessful attempt was made to mine these coals. The southern Alaskan coals have been worked spasmodically for local use ever since the Territory was transferred. Thus Dall, in 1872, mined coal at Coal Bay, Unga Island,[b] for the United States steamship *Humboldt*, which he commanded, and mining at this locality has gone on intermittently and in a small way for many years.

In 1888[c] the Alaska Coal Company started some mining at Kachemak Bay. The same company and the North Pacific Mining and Transportation Company continued mining in this locality for a number of years. Since 1899 the Cook Inlet Coal Fields Company seems to have controlled this field and is now carrying on rather extensive operations. In 1893 mining in a crude manner was inaugurated at Chignik River and has since been intermittently carried on by the Alaska Packers' Association.

In southeastern Alaska considerable prospecting has been done at Killisnoo, and the Firestone mine, owned by James McCluskey, which was established in 1880, has been occasionally worked for local use. Though the output is small, it must be classed as a working mine. In 1898 the Admiralty Coal and Fuel Company was established, and during the season of 1900 did considerable development work.

In 1889 the Alaska Mining and Development Company was organized to develop the coals at Herendeen Bay, on the western side of the Alaska Peninsula. The Alaska Commercial Company subsequently gained control of this enterprise, but it does not seem to have been a financial success.

The coals of the Yukon River attracted very little attention, though a few crude attempts at mining were made, until the excitement which attended the discovery of gold in the Klondike region in 1897. Within a year there were probably upwards of a hundred steamers on the Yukon River, and while the banks will furnish ample wood for some years, yet that easiest of access was rapidly being cut. Wood commanded anywhere from $8 to $20 a cord. Moreover, on the lower Yukon, below the Holy Cross Mission, there is no timber of any kind, and the steamers were forced to carry a supply of fuel wood from higher up the river sufficient to last them for the voyage to St. Michael and return.

[a] Dall, op. cit., p. 773. [b] Op. cit. [c] Dall, op. cit., pp. 791 and 793.

Some of the larger companies soon saw the advantage in the use of coal, and a supply of it was kept in store at St. Michael for use of the river steamers. The disadvantage of this coaling station is that when a steamer is taking her heaviest cargo of freight on her up trip she must carry her largest quantity of coal. If coal could be found on the upper river the steamers running to St. Michael would bring it down very cheaply and distribute it along the river at points where it is needed. These conditions have led to considerable investigations of the coal supply of the Yukon River, and at several localities organized attempts have been made to open up the coals.

Since steamers were introduced on the Lewes River, in 1898, the coal deposit near Rink Rapids has been opened up. On the Nordenskiold River the Porter Bros. have made some developments on a coal vein. These are both in Yukon Territory. The North American Trading and Transportation Company has opened up a considerable mine on Cliff Creek, which is on the Canadian side of the boundary. This plant includes a small railway and locomotive. On Coal Creek, also in Yukon Territory, the Alaska Exploration Company has a producing mine. This same company during 1900 started some developments on the Alaskan side of the line, about 60 miles above Circle City.

The oldest mine on the Yukon is opposite the mouth of Hess Creek. This location was formerly known as Miller's mine, now as Drew's mine. The workings are quite extensive and the equipment includes a steam hoisting apparatus, coal bunkers, etc. The Pioneer mine, some distance below Hess Creek and 30 miles above Rampart, has a similar equipment. Both of these mines produced considerable coal in 1900, which was sold chiefly to steamers.

Near Nulato, the Blatchford and Pickart mines produced some coal, but were worked in a smaller way. Similarly, the Clemens Thein mine and the Williams mine, both between Anvik and Nulato, were coal producers in a small way.

Mention has already been made of the discovery of coal at Cape Lisburne, in the early part of the century, and the subsequent development of the seams for use of whalers and revenue cutters. As a result of the rapid development of the Nome gold fields, these, the nearest coal deposits, have received some attention. The Corwin Trading Company is now engaged in a systematic attempt to develop these deposits to supply Nome and the whaling ships. The latter have in the past always brought their coal from Puget Sound.

CONCLUSION.

In the foregoing an attempt has been made to summarize the existing knowledge of the coal resources of Alaska. It has been shown that coal-bearing rocks have a wide distribution in the Territory; that the coals are chiefly lignites, with some bituminous coals, and in a few localities semianthracites.

Developments have been entirely along waterways, where the coal could be handled cheaply and receive the benefit of water transportation. The southeastern and southwestern Alaska coal fields, as far as developed, are on tide water along a coast line affording good harbors which are open to navigation the entire year. They can be mined comparatively cheaply, and while many of them are not equal in quality to the other Pacific coast coals, yet they have found a ready market for local steamboat and domestic use. No developments have been made of the higher grade coals which are known to occur in southern Alaska, except in a few localities, where the faulted conditions of the seams and associated beds prevented economic mining. These higher grade coals are worthy of the attention of the prospector and capitalist. If found to occur in sufficient quantities they could compete with all other coals in the Pacific coast market.

The development of the Yukon coals is dependent entirely on their finding a local market. Because of their low grade, of the expense of mining them, and the cost of transportation, they could never be exported. As long as the placer mines of the Yukon Basin continue to make a large annual output of gold, these Yukon coal mines will find ready sale for their products. As in southern Alaska, so also in the Yukon Basin, the coals seem to vary greatly in character. It should be the aim of prospectors and mining companies to do careful preliminary work before developing a mine, and thus avoid opening up low-grade lignite seams. The Yukon coals are said to bring about $15 a ton at the mines.

Nome has offered a splendid market for coal during the last two years. Probably very little has sold as low as $25, and it has gone up as high as $75, or even $100, per ton, with an average during the summer of 1900 of about $40 to $50. It was this that led to the development of the Cape Lisburne field, which is only 200 miles away. These mines would also supply fuel to whalers, who use large quantities of coal on their cruises in the Arctic Ocean.

In 1900 about 13,000 tons of coal were shipped as cargo to Alaska from Washington ports, and the amount imported from British Columbia into Alaska was probably considerably more. No accurate data as to the coal produced by Alaskan mines are obtainable, but the total is probably between 4,000 and 5,000 tons, of which about a third is from mines on the Yukon River.

Besides the coal there are three other possible sources of fuel supply in Alaska—timber, petroleum, and peat. Of these the first is the only one which has been used.

Southeastern Alaska is heavily forested and affords timber which is ample for fuel. Certain species of trees are found as far west as Kodiak Island. Beyond Kodiak to the west and north the coast region of Alaska is practically treeless. The sheltered regions afford some willows and occasionally a little spruce, but for the most part the coastal belt is covered simply with moss, grass, and low shrubs. This type of vegetation extends northward to Point Barrow, and from there eastward. These moss and grass covered plains and rolling plains are termed "tundras," and are found encircling the globe as the northern continental margins.

The interior of Alaska has usually a sufficient supply of wood for the ordinary purposes of building and mining and for fuel. The larger river valleys, such as that of the Yukon, are often heavily forested with spruce and other trees. On the Yukon, near the international boundary, the timber line stands at about 3,000 feet; northward it decreases in elevation, and on the Koyukuk is about 2,500 feet. Still farther to the north and west it further decreases in altitude, and on the Upper Kowak the timber is said to be limited to the floor of the larger river valleys. In the northern Arctic drainage, according to all reports, there is no timber except the willows, which, however, grow to considerable size. The Kuskokwim, Sushitna, and Copper rivers all have timbered basins. During the great influx of population of the last three years much timber has been destroyed by fire in the dry summer months.

In the north and northwest part of the Territory, from Norton Bay around to the mouth of the Mackenzie, the shore was once abundantly supplied with driftwood. The Eskimos, who have been using this wood for generations, are very economical in the matter of fuel, and until the coming of the white man the probabilities are that the wood was accumulated faster than it was used. This driftwood is brought down from the interior by the larger rivers, whose banks are wooded. The cutting of the wood along the banks of the Yukon has already decreased the annual contribution of driftwood to the northern Bering Sea. This, together with rapid exhaustion by the white man of the supply which had accumulated in the past, will soon cause the Eskimo as well as the white man to be dependent on other sources for fuel. The north Arctic coast eastward from Point Barrow, which is but thinly populated by natives and seldom visited by whites, has some driftwood. The possibilities of using for fuel the thick growth of vegetable matter which covers most of the treeless regions of Alaska has been suggested, but has never been put to practical test. During the months of June and July, 1900, extensive fires swept through much of the treeless region of Nome and other portions of the Seward Peninsula. The moss and grass when dry were found to burn rapidly with considerable flame, and fires ran nearly over the entire region visited by prospectors during the dry months. This fact makes it evident that the surface growth of the tundra could be used for fuel, provided it were properly dried. This material has in many places been accumulated to considerable thickness as peat bogs.

Of the third source of fuel supply, petroleum, we have no definite knowledge of the existence in commercial quantities. It is reported to have been found in southern Alaska, between Yakutat and Controller bays, and also on the west side of Cook Inlet near Kachemak Bay.

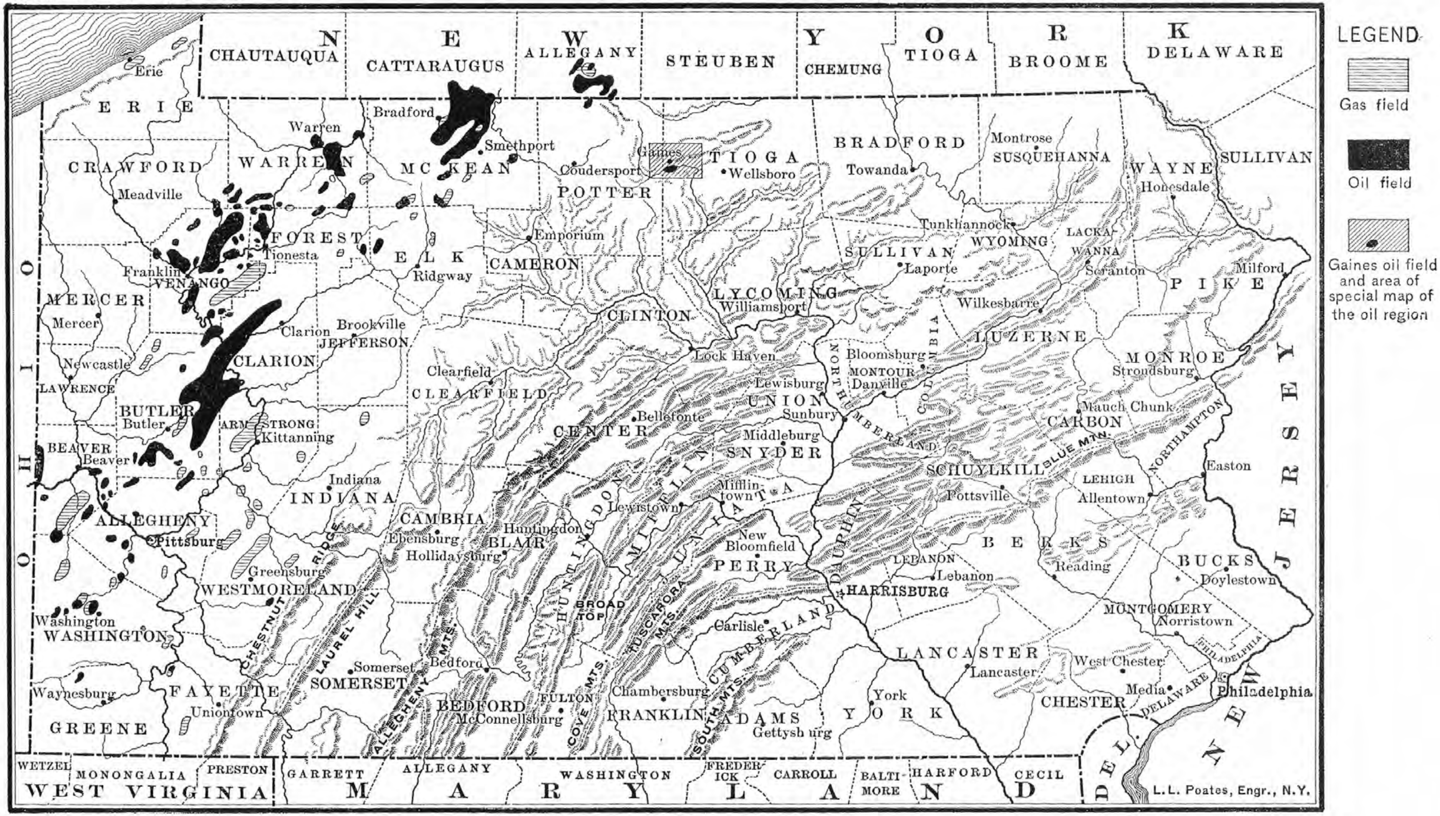
THE GAINES OIL FIELD OF NORTHERN PENNSYLVANIA

BY

MYRON L. FULLER

CONTENTS.

ILLUSTRATIONS.



MAP OF PENNSYLVANIA, SHOWING THE LOCATION OF THE GAINES OIL POOL AND ITS POSITION RELATIVE TO OTHER OIL AND GAS POOLS AND TO THE APPALACHIAN RIDGES.

Topography after J. P. Leslie. Location of oil and gas pools after C. A. Ashburner.

THE GAINES OIL FIELD OF NORTHERN PENNSYLVANIA.

By Myron L. Fuller.

INTRODUCTION.

LOCATION.

The Gaines oil field is located near the western boundary of Tioga County, Pa., at a point 17½ miles south of the New York State line. It extends for about 3 miles along the borders of Pine Creek in a slightly northeast-southwest direction, passing near the villages of Watrous, Gaines, and Manhattan, in Gaines Township. The field lies about 50 miles east and 10 miles south of the well-known Bradford oil field, and from 20 to 25 miles south and about 15 miles east of the Allegany field of New York. It is of special interest as being 20 miles nearer the Allegheny Front than any other producing field in northern Pennsylvania. Its relation to the Appalachian folds, as indicated by their ridges, and to the oil fields of McKean, Warren, Venango, and Butler counties is shown on the accompanying map, Pl. XXXVI.

FIELD WORK AND ACKNOWLEDGMENTS.

The field work, upon which is based the discussion of the Gaines oil field and of the geology of the surrounding region, was done mainly during the month of September, 1900, but the field was revisited in April, 1901, with the view of bringing the information as nearly as possible to date and of connecting the wells by a system of accurate levels.

The collection of information bearing upon the oil was greatly facilitated by the uniform kindness and courtesy of the oil operators. Special thanks are due to Mr. John L. McKinney, president, and to Mr. J. H. Leslie and Capt. James C. Gibney, local superintendents of the South Penn Oil Company; Mr. H. I. Brewster, manager of Billings Oil and Gas Company; H. R. Whittaker, manager of Blossburg and Gaines Oil and Gas Company; H. N. Sherwood, secretary of Wellsboro Oil and Gas Company; T. C. Campbell, president of Knoxville Oil and Gas Company; C. R. Scott, of Scott & Fay Oil Company; J. G. Ryan, of Maxwell Oil Company; D. L. Goudy, foreman

of South Penn Oil Company; L. D. Strayer, foreman of Scott & Fay Oil Company; D. J. Hale, contractor for South Penn Oil Company; D. A. Paddock, and Charles Clark.

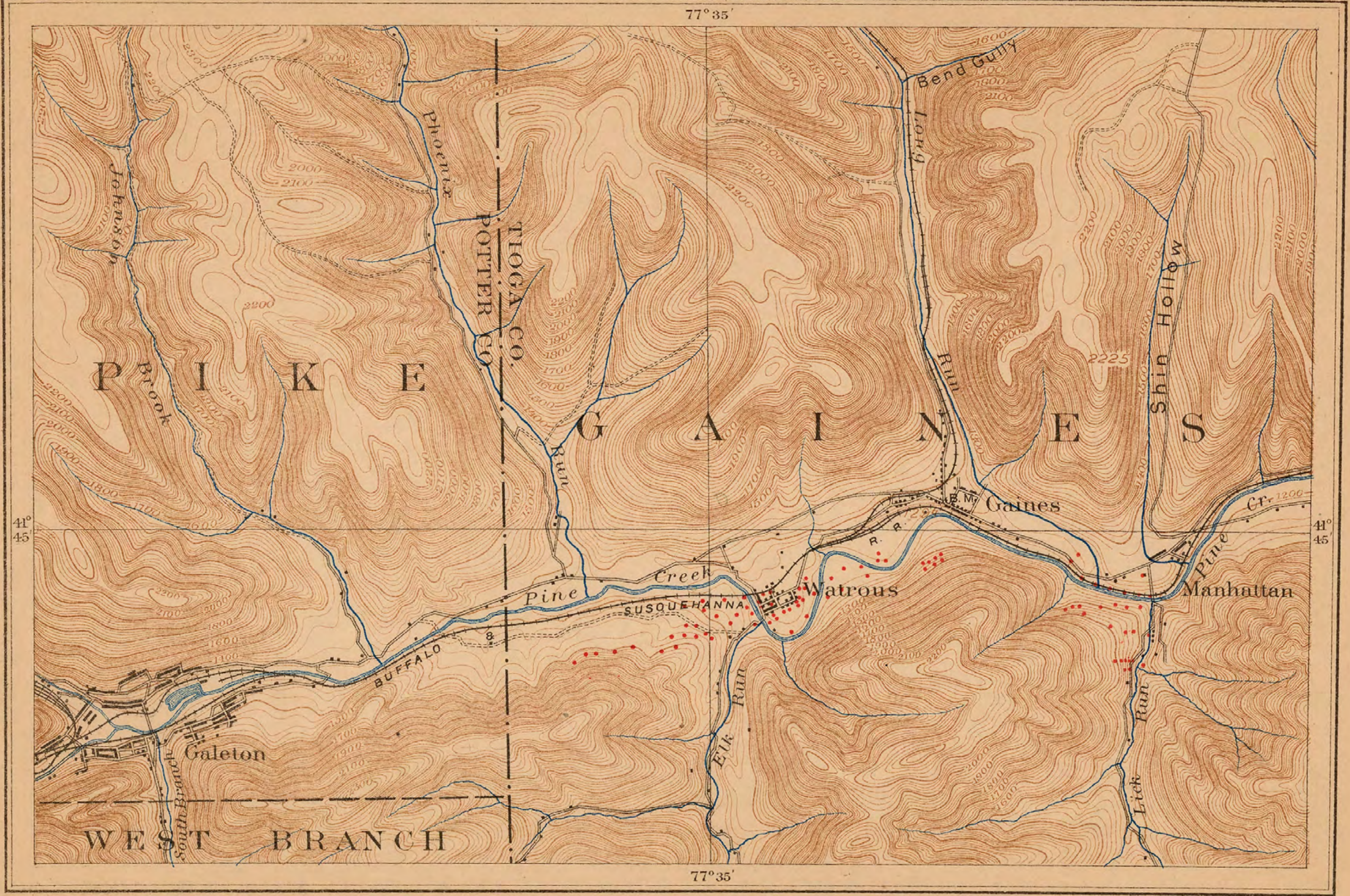
DESCRIPTION OF THE OIL FIELD.

TOPOGRAPHY.

Pine Creek, along which the Gaines oil field extends, is a branch of the Susquehanna River. Its source is in Sweden Township, Potter County. From here it flows eastward and southeastward through Jackson, Pike, Gaines, and Shippen townships to Ansonia, where it unites with Marsh Creek. From its source to Galeton its course is diagonally across the rather flat rock folds of the western division of the Appalachian province, but at this village it makes a bend to the left, following a line parallel to the folds as far as Ansonia, where, after uniting with Marsh Creek, it turns to the south and runs directly across the strike of the folds for a distance of 40 miles or more, finally emptying into the West Branch of the Susquehanna near the town of Jersey Shore.

Throughout nearly the whole of this distance it flows through a deep gorge, sometimes almost meriting the name canyon, which has been cut to a depth of 800 to 1,000 feet or more in sandstones and shales of Devonian and Carboniferous age. This gorge is well developed in the vicinity of the Gaines oil field, at which point the river bottom is more than 1,000 feet below the surrounding uplands. Not only does the main stream occupy a deep gorge, but the tributaries which enter it from time to time likewise flow in deep, steep-sided valleys. Elk, Long, and Phœnix runs, all of which enter Pine Creek in the vicinity of the oil field, occupy such gorges, the bottoms of which are cut nearly to the level of the main stream. Their direction of flow is directly across the trend of the folds. Lick Run and Shin Hollow, on the other hand, are good examples of a class of valleys in which the streams, though cutting deep and sharp valleys, have not had sufficient volume and power to reduce the bottoms of their valleys to the level of the main valley.

A noticeable feature of the ridges separating the gorge-like valleys is the level character of the crests, which rise to nearly uniform heights above the river near Gaines and at many other points along the course of Pine Creek. Near Gaines the walls of the valleys rise more than 1,000 feet in a distance of less than a mile, but when the crests of the ridges between the streams are once reached, there is often a difference in elevation of only 40 or 60 feet in a distance of several miles. These level-crested ridges represent the remnants of a once continuous, smooth, or gently undulating surface, known as a peneplain, which originally lay at a much lower level with reference to the sea, but which was subsequently uplifted and eroded by stream



TOPOGRAPHIC MAP OF THE GAINES OIL REGION, PENNSYLVANIA

Scale

1 ½ 0 1 MILE

Contour interval 20 feet

Datum is mean sea level.

Producing oil wells

action until at present only the level-topped ridges remain. This feature is well brought out by the contours of the accompanying map, Pl. XXXVII.

While in the region under consideration Pine Creek follows in a general way a line parallel to the strike of the rock folds, it sometimes deviates considerably from such a line as it swings from side to side. The oil belt, as a whole, follows the strike of the rocks very closely and is consequently crossed a number of times by Pine Creek. The larger number of wells in the producing belt lie along the lowlands bordering the river, but west of Watrous and near Gaines and Manhattan a considerable number lie well up the hillside. Some of the producing wells are situated from 200 to 250 feet above the bottom of the valley.

The bottom portion of the valley of Pine Creek is locally characterized by the presence of terraces with upper surfaces standing from 50 to 70 feet above the present bed of the stream, representing, in part at least, the remnants of delta deposits which were once continuous across the valley and which were deposited by streams entering the main valley from the tributary valleys on the north when the ice sheet covered the northern portion of the continent in Pleistocene time. The towns of Gaines, Watrous, and Manhattan are all situated on terraces of this nature. The full height of the terraces is not due to the deposits of the delta gravels, as the latter lie upon rock terraces, the surfaces of which are themselves 40 feet or more above the stream bed.

The immediate bottom of the valley of Pine Creek is characterized by a flood plain, but it is not well developed and is generally narrow and fragmentary in character. A considerable number of the successful wells are situated upon this flood plain, both at Watrous and near Manhattan. Several such wells near the latter village are shown on the right of the view in Pl. XXXVIII. The wells on the left are located upon the edge of the rock terrace mentioned above.

LIMITS OF THE FIELD.

The Gaines oil field embraces two distinct pools, separated by an unproductive area a little over half a mile in width. The first and most westerly of these pools centers about the village of Watrous, and may be designated the Watrous pool. Its supply of oil is derived from a fine-grained sandstone, known to drillers as the Atwell sand. The second or easterly pool lies along Pine Creek about the mouths of Long and Lick runs, near the village of Manhattan, and may be designated the Manhattan pool. The oil is obtained from a series of shales, shaly sandstones, etc., known to the drillers as the "Blossburg formation."

The western limit of the Watrous pool is marked by the Scott & Fay well No. 5, on the C. H. Watrous lot. From this point, at which the producing belt is probably not over 200 or 300 feet in width, it extends in a direction about 16° north of east through the village of Watrous, finally terminating in the Knoxville wells Nos. 3 and 5, about half a mile south of Gaines. The total length of the producing belt is a little less than 2 miles, and its greatest breadth (near Watrous) 600 to 800 feet. It is cut four times by the meanders of Pine Creek, the wells lying partly along the bottom lands and partly on the hillsides to the south.

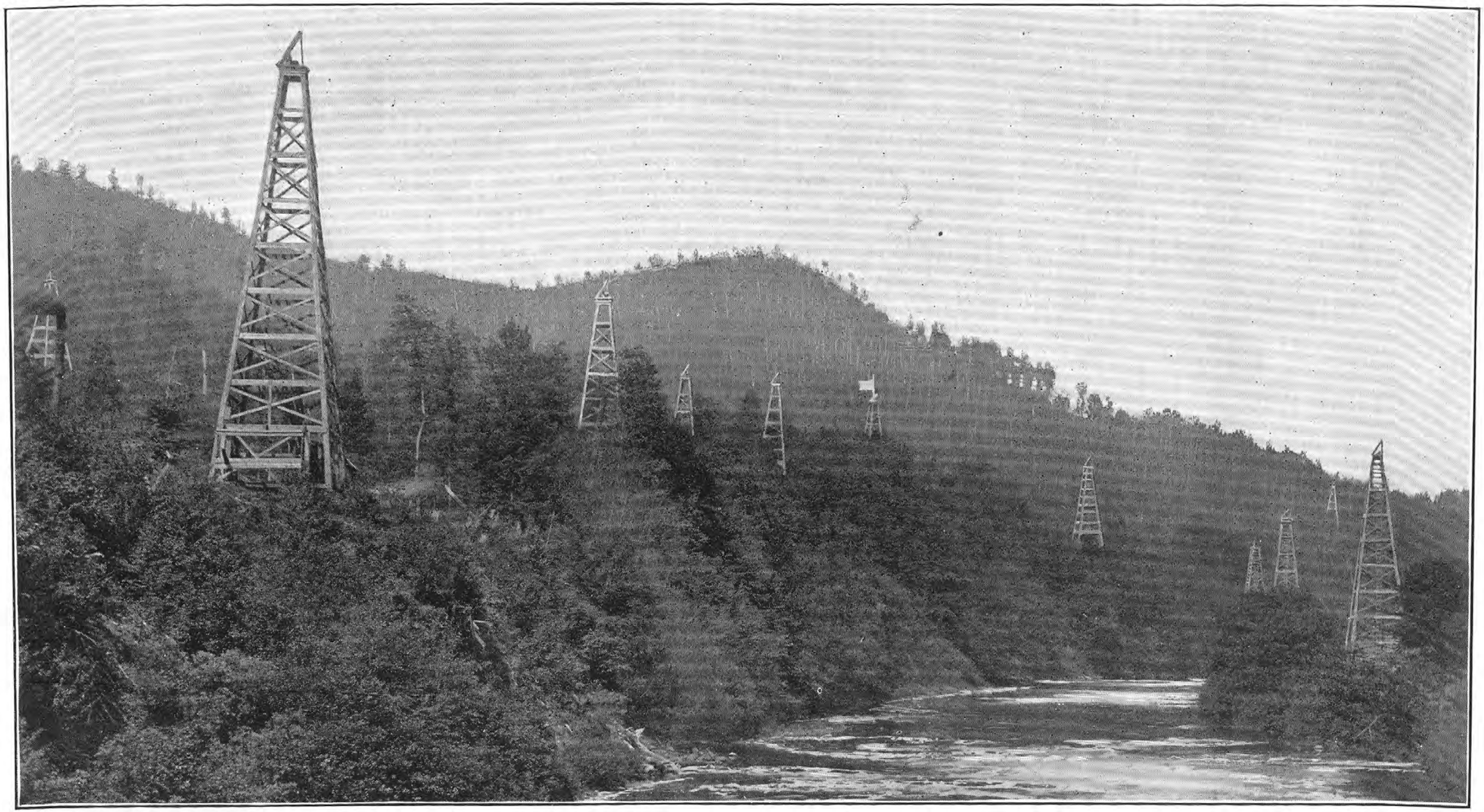
The Manhattan pool is more compact and is roughly oval in outline. Its east-west diameter is about half a mile; the north-south diameter is slightly greater. The wells lie both along the lowlands bordering Pine Creek and upon the hillsides to the south. A general view of the wells along the flood plain and rock terrace bordering Pine Creek is given in Pl. XXXVIII. The most westerly of the producing wells of the Manhattan pool are the Wellsboro wells Nos. 1 and 2 on the north bank of Pine Creek and the Wellsboro wells on lot 12 on the hillside south of the creek. The interval between these wells and the Knoxville wells of the Watrous pool is about 2,800 feet. The northern limit of the Manhattan pool is marked by the line of Wellsboro wells north of Pine Creek, the eastern limit by Wellsboro No. 9 and Blossburg No. 9, and the southern limit by Billings No. 4.

The relative positions of the two pools and their relations to the topography are shown in Pl. XXXVII. The locations of the individual wells are shown on an enlarged scale in Pl. XXXIX.

EARLY OPERATIONS.

When a number of successful wells have been sunk in a region it usually happens that at least a portion of them will fall into a sort of linear system. Lines are frequently established through a number of such wells and are afterwards prolonged into adjacent territory and used as a guide in the sinking of new wells. These are known to oil men as degree lines. Where the wells upon which the degree lines are based are located along a line of strike it will be readily seen that the resulting line will be of great value as long as the strike remains constant. Unfortunately, however, degree lines often have no geologic or other scientific basis, but are evolved from insufficient data or from none at all. Lines which have proved successful in one region have frequently been applied to new regions without regard to differences in geologic conditions.

The sinking of test or "wild-cat" wells along such degree lines, even where the latter have little or no foundation, has sometimes added much to the general knowledge of the distribution of oil, and has brought about the discovery of new and isolated pools. The discovery of the Gaines oil field itself, in a certain sense at least, may be considered as the result of the running out of such a degree line from the Bradford field at the time of the excitement attending the discovery and development of that field. From this field, which lies some 50 miles west and 10 miles north of Gaines, degree lines were run



VIEW OF OIL WELLS ALONG PINE CREEK, WEST OF MANHATTAN.

out in various directions, and were the basis for the sinking of a number of scattering wells in Tioga and Potter counties. With the exception of a little gas, nothing was obtained.

The degree line which passed through the village of Gaines seems to have had no geologic foundation whatever, but it suggested to Mr. S. X. Billings, a prominent landowner and timber operator, the idea of sinking a well in search of oil. His death, however, prevented the accomplishment of his wish, but in 1884 his son, Mr. C. F. Billings, put down a well near the spot selected by his father. This well was located on the flat bottom lands bordering Long Run, about 60 rods east of the railroad station in the northern portion of the town of Gaines, and about half a mile north of the eastern extremity of the Watrous pool as it has been defined by the recent developments. The well was sunk to a depth of 1,345 feet. Gas and a little oil were encountered at 1,240 feet below the surface. An 80-quart charge of nitroglycerin was exploded at this point, and a little green oil was afterwards bailed out, but salt water interfered and the well was abandoned. This well has the distinction of being the only well at Gaines of which a complete record appears to have been kept. It is here given in full:

Record of the Billings well No. 1 (old), April, 1884.[a]

[Authority: D. A. Paddock.]

Character of rock.	Thickness in feet.	Depth in feet.
Conductor	13	13
Sandstone, hard, blue	1	14
Shale, blue	4	18
Red rock	20	38
Slate	23	61
Red rock	48	109
Shale, blue	20	129
Red rock	40	169
Sandstone, gray	2	171
Red rock	22	193
Slate	24	217
Red rock	23	240
Slate and shells	15	255
Sandstone, gray	10	265
Red rock	20	285
Slate and shells	17	302
Slate, gray (salt water)	18	320
Red rock, dark	30	350
Sandstone, gray	10	360
Shells and slate	3	363
Sandstone, hard, gray	10	373
Slate, black	15	388
Sandstone, hard, dark gray	9	397
Slate and shells	20	417
Slate and shells, hard, dark	35	452
Sandstone, gray, hard	26	478
Slate and shells	40	518
Sandstone, dark reddish	45	563
Slate and shells	30	593
Slate	22	615

[a] Second Geol. Survey Pennsylvania, Rept. I 5, pp. 147-148.

Record of the Billings well No. 1 (old), April, 1884—Continued.

Character of rock.	Thickness in feet.	Depth in feet.
Slate and shells	30	645
Sandstone, gray	10	655
Slate, soft	18	673
Slate and hard shells	7	680
Slate and shells	40	720
Slate	25	745
Shells, hard	5	750
Sandstone, gray	30	780
Slate	20	800
Shells and sand	15	815
Sandstone	31	846
Slate and shells	43	889
Shells, hard	12	901
Slate, gray	29	930
Sandstone, gray	50	980
Sandstone, gray, hard	20	1,000
Slate	60	1,060
Slate and shells	20	1,080
Slate	20	1,100
Sandstone, gray, dark	135	1,235
Sandstone, dark (some oil and gas)	5	1,240
Sandstone, dark gray	26	1,266
Sandstone, gray	19	1,285
Sandstone, gray, slate and shells	60	1,345

In 1885 the Gaines Oil and Gas Company, encouraged by the show of oil obtained in the Billings well, put down a well 3 miles east of Gaines, at a point near the railroad and creek. This well is said to have penetrated to a depth of about 1,200 feet but failed to find oil, though gas under considerable pressure was encountered. This well, known as the Rexford well, was cleaned out in 1899, but no oil and only a little gas was obtained.

The year 1886 was marked by the sinking of three additional wells by the Gaines Oil and Gas Company. The most easterly of these was situated on Asaph Run, northeast of Ansonia, and about 10 miles east of Gaines. Nothing was obtained. The second well was located 40 rods south of Pine Creek, on warrant 4317, Pike Township, Potter County, and was some 3 miles west of Gaines. The well was drilled to a depth of 1,835 feet and gave oil shows at 1,100 and 1,255 feet. A light shot at 1,255 feet was without result. The well was then plugged at 1,200 feet and an 80-quart charge exploded at 1,100 feet, but only salt water and gas were obtained. The sand at 1,255 feet is said to have been identical in character with the typical Bradford producing sand. The third well was located on Johnson Brook, Pike Township, about a mile north of the preceding. Small amounts of gas were encountered at a number of horizons, and a small oil show below 1,366 feet, but the quantities were so slight that the well was abandoned without further testing.[a]

[a] The records of these early wells are given in full in Second Geol. Survey Pennsylvania, Rept. I 5, pp. 47-50.

All of these early wells were sunk along the north flank of the anticline passing northeastward and eastward near the villages of New Bergen, Germania, Marshfield, Wellsboro, etc. They are generally not far from a line drawn midway between the crest of this anticline and the trough of the syncline lying immediately to the north. A large field, if it had existed, would have been brought to light by these earlier drillings, but the narrow belt constituting the Gaines oil field, with a width of only a few hundred feet, was missed, though the nearest well came within half a mile of it.

The negative results of the early operations naturally discouraged the drilling of new wells for a considerable number of years. It was not until 1898, after the discovery of oil shows near Galeton, that active search was again made in the Gaines region.

RECENT DEVELOPMENTS.

The first of the recent wells in the Gaines field was drilled in 1898 by Woodward & Co. (Wellsville Oil and Gas Company), of Wellsville, N. Y. The company had previously encountered a sufficient show of oil near Galeton to encourage a further trial of the region. The Gaines well was located on the Atwell farm, east of Watrous. Oil was encountered in the sandstone afterwards known as the "Atwell sand," but after the sand had been penetrated to a distance of 5 feet the well filled with salt water and was abandoned.

Owing to the financial embarrassment of the company sinking the original well, the drilling apparatus passed into the hands of E. M. Atwell, who sank a well 500 feet farther south and higher up the flank of the anticline. The well was a success, and others were immediately sunk upon his own farm and upon the Dimmick farm.

The oil was found in a dark-gray to brown and black sandstone, at depths varying from a little over 700 to nearly 900 feet. The sandstone had a gentle northward dip, but the differences in the depths of the wells was largely dependent upon the elevations at which the wells started. The sand was given the name "Atwell" in honor of the owner of the first producing well.

Following the sinking of these wells, others were put down in rapid succession, and the oil-producing area was rapidly extended westward to a point a mile or more beyond Watrous, while a new formation, known as the "Blossburg," was discovered about 2 miles to the east and at an elevation of 200 feet above the Atwell sand. The wells in the Atwell sand increased to nearly 70 in 1900, and others were still drilling. In the same period the number of producing wells in the "Blossburg formation" increased to about 30. In the Atwell sand the wells were generally small, but the supply was fairly constant and there were few dry holes, probably 8 out of every 10 of the wells sunk being productive. In the "Blossburg formation" a larger percentage of the drillings resulted in failure, and the flows, though much greater than the initial flows from the Atwell sand, declined more rapidly, and the wells in many cases were soon exhausted. The relative amounts and the permanancy of the flows from the wells of the two formations are discussed on pages 599 to 601.

LOCATION OF WELLS.

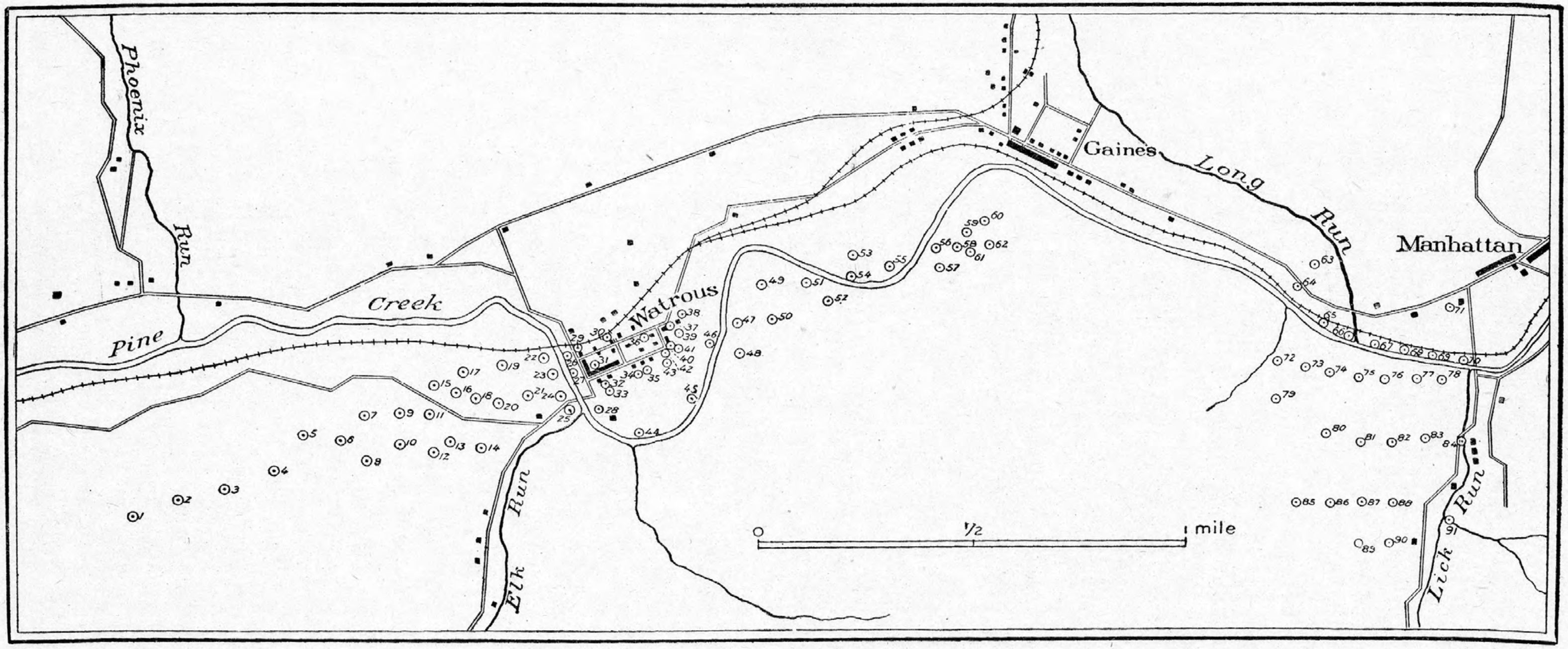
In the sketch map of the Gaines oil field (Pl. XXXIX) the extent, form, and relative positions of the two oil pools are clearly shown by the productive wells, which are designated by numbers referring to the "Index to wells," below.

The crowded condition of the wells in the Watrous pool is a noticeable feature, especially along the southern edge of the town, where there are several instances of wells sunk within a distance of 100 feet or less from one another. It is almost needless to state, however, that wells in such close proximity were not sunk by the same company. To secure the greatest amount of oil at the least cost, it is considered that the intervals between wells sunk in the Watrous field should be at least 300 or 400 feet, and some such interval is usually rigidly maintained in the developments of a single company. In wells separated by very short intervals the individual supplies can not fail to be adversely affected by their mutual interference.

In the outlying portions of the Watrous pool, the wells are more scattering, and in the western extension are limited by the narrowness of the producing belt to a single line. In the "Blossburg formation" the wells are less crowded than in the case of the wells of the Atwell sand, but the productive area is, nevertheless, thoroughly covered.

Index to wells of Pl. XXXIX.

No. on map.	Name of well.	No. on map.	Name of well.
	Scott & Fay:	15	Maxwell Oil Co., No. 10.
1	C. H. Watrous lot, No. 5.	16	Maxwell Oil Co., No. 7.
2	C. H. Watrous lot, No. 8.	17	Maxwell Oil Co., No. 12.
3	C. H. Watrous lot, No. 7.	18	Maxwell Oil Co., No. 9.
4	C. H. Watrous lot, No. 6.	19	Maxwell Oil Co., No. 3.
5	C. H. Watrous lot, No. 2.	20	Maxwell Oil Co., No. 6.
6	W. H. Watrous lot, No. 10.	21	Maxwell Oil Co., No. 5.
7	W. H. Watrous lot, No. 6.	22	Maxwell Oil Co., No. 2.
8	W. H. Watrous lot, No. 8.	23	Maxwell Oil Co., No. 11.
9	W. H. Watrous lot, No. 11.	24	Maxwell Oil Co., No. 4.
10	W. H. Watrous lot, No. 4.	25	Maxwell Oil Co., No. 1.
11	W. H. Watrous lot, No. 1.		South Penn Oil Co.:
12	W. H. Watrous lot, No. 7.	26	Legal, No. 7.
13	W. H. Watrous lot, No. 2.	27	Legal, No. 6.
14	W. H. Watrous lot, No. 5.	28	Dimmick, No. 9.



INDEX MAP, SHOWING LOCATION OF OIL WELLS.

Index to wells of Pl. XXXIX—Continued.

No. on map.	Name of well.
	South Penn Oil Co.—Continued:
29	Legal, No. 5.
30	Legal, No. 1.
31	Legal, No. 3.
	Renova Oil Co.:
32	Murphy, No. 1.
	South Penn Oil Co.:
33	Dimmick, No. 6.
34	Dimmick, No. 3.
35	Legal, No. 2.
36	Legal, No. 4.
37	Dimmick, No. 4.
38	Dimmick, No. 8.
	Blossburg Oil and Gas Co.:
39	Watrous, No. 2.
40	Watrous, No. 1.
	South Penn Oil Co.:
41	Dimmick, No. 5.
42	Hovey Oil Co., No. 1.
	South Penn Oil Co.:
43	Dimmick, No. 12.
44	Dimmick, No. 7.
45	Dimmick, No. (?).
46	Dimmick, No. 1.
	South Penn Oil Co.:
47	Atwell, No. 3.
48	Atwell, No. 7.
49	Atwell, No. 2.
50	Atwell, No. 4.
51	Atwell, No. 6.
52	Atwell, No. 5.
53	Atwell, No. 1.
54	Atwell, No. 13.
55	Atwell, No. 8.
56	Atwell, No. 11.
57	Atwell, No. 10.
58	Knoxville Oil and Gas Co., No. 1.
59	Knoxville Oil and Gas Co., No. 4.
60	Knoxville Oil and Gas Co., No. 5.
61	Knoxville Oil and Gas Co., No. 2.
62	Knoxville Oil and Gas Co., No. 3.
63	Wellsboro Oil and Gas Co., No. 1.
64	Wellsboro Oil and Gas Co., No. 2.
65	Wellsboro Oil and Gas Co., No. 3.
66	Wellsboro Oil and Gas Co., No. 4.
67	Wellsboro Oil and Gas Co., No. 5.
68	Wellsboro Oil and Gas Co., No. 6.
69	Wellsboro Oil and Gas Co., No. 7.
70	Wellsboro Oil and Gas Co., No. 8.
71	Wellsboro Oil and Gas Co., No. 9.
72	Wellsboro Oil and Gas Co., lot 12, No. 2.
73	Blossburg & Gaines Oil and Gas Co., No. 3.
74	Blossburg & Gaines Oil and Gas Co., No. 4.
75	Blossburg & Gaines Oil and Gas Co., No. 5.
76	Blossburg & Gaines Oil and Gas Co., No. 6.
77	Blossburg & Gaines Oil and Gas Co., No. 7.
78	Blossburg & Gaines Oil and Gas Co., No. 8.
79	Wellsboro Oil and Gas Co., lot 12, No. 1.
80	Blossburg & Gaines Oil and Gas Co., No. 13.
81	Blossburg & Gaines Oil and Gas Co., No. 12.
82	Blossburg & Gaines Oil and Gas Co., No. 11.
83	Blossburg & Gaines Oil and Gas Co., No. 10.
84	Blossburg & Gaines Oil and Gas Co., No. 9.
85	Billings Oil and Gas Co., No. 5.
86	Billings Oil and Gas Co., No. 3.
87	Billings Oil and Gas Co., No. 2.
88	Billings Oil and Gas Co., No. 1.
89	Billings Oil and Gas Co., No. 6.
90	Billings Oil and Gas Co., No. 4.
91	South Penn Oil Co., Lick Run well.

ELEVATION OF WELLS.

In order to determine the geologic structure with a view to use as a base in the selection of locations for new wells, a line of spirit levels was run from bench marks of the United States Geological Survey to each of the wells represented in Pl. XXXIX. The elevations as given are for the floors of the derricks, which usually correspond with the tops of the drivepipes, and represent the elevations in feet above sea level.

From the elevations of the well mouths the elevations of the top of the sandstone in the wells of the Atwell sand and the pay streaks in the case of the wells of the "Blossburg formation" have been calculated and are given in the table.

A comparison of the depths of the sand in the various wells shows that the dip of the Atwell sand is a little west of north. In the Dimmick well No. 7 (44 on map) the elevation of the sand is 544 feet. From here the sand dips to the northwest, until in the Legal well No. 1 (30 on map) it has an elevation of 463 feet, indicating a dip of 81 feet in a quarter of a mile, or about 6 feet in 100. The structure will be considered in detail in the discussion of the geologic structure (pp. 616–621).

Elevations of wells of the Atwell sand, including depth, thickness, and elevation of the producing sand.

[Elevations are given in feet above sea level as determined by spirit leveling by the United States Geological Survey.]

Company and well.	No. on map, Pl. XXXIX.	Elevation of well.	Depth to top of sand.	Thickness of sand.	Elevation of sand.
South Penn Oil Co.:					
Atwell No. 1	53	1,258	791	....	467
Atwell No. 2	49	1,240	772	14	468
Atwell No. 3	47	1,242	762	15	480
Atwell No. 4	50	1,273	783	17	490
Atwell No. 5	52	1,235	736	15	499
Atwell No. 6	51	1,236	762	14	474
Atwell No. 7	48	1,279	767	12	512
Atwell No. 8	55	1,235	741	21	494
Atwell No. 9	....	1,300	772	18	528
Atwell No. 10	57	1,380	882	23	498
Atwell No. 11	56	1,335	856	15	479
Atwell No. 12	....	....	887	21	....
Atwell No. 13	54	1,231	760	20	471
Dimmick No. 1	46	....	761	16	....
Dimmick No. 3	34	1,263	755	17	508
Dimmick No. 4	37	1,261	796	12	465

Elevations of wells of the Atwell sand, including depth, thickness, and elevation of the producing sand—Continued.

Company and well.	No. on map, Pl. XXXIX.	Elevation of well.	Depth to top of sand.	Thickness of sand.	Elevation of sand.
South Penn Oil Co.—Continued.					
Dimmick No. 5	41	1,245	756	17	489
Dimmick No. 6	33	1,264	751	13	513
Dimmick No. 7	44	1,249	705	....	544
Dimmick No. 8	38	1,244	781	15	463
Dimmick No. 9	28	1,265	741	24	524
Dimmick No. 10	......	....	801	....	....
Dimmick No. 11	......	1,279	769	17	510
Dimmick No. 12	43	1,247	745	18	502
Legal No. 1	30	1,267	804	19	463
Legal No. 2	35	1,260	756	16	504
Legal No. 3	31	1,272	779	13	493
Legal No. 4	36	1,262	790	13	472
Legal No. 5	29	1,270	790	14	480
Legal No. 6	27	1,249	754	15	495
Legal No. 7	26	1,265	780	15	485
Maxwell Oil Co.:					
Maxwell No. 1	25	1,251	713	17	538
Maxwell No. 2	22	....	775	....	....
Maxwell No. 3	19	1,256	790	....	466
Maxwell No. 4	24	1,254	745	17	509
Maxwell No. 5	21	1,263	755	17	508
Maxwell No. 6	20	1,258	740	18	518
Maxwell No. 7	16	1,299	813	21	486
Maxwell No. 8	......	....	799	14	....
Maxwell No. 9	18	1,283	780	18	503
Maxwell No. 10	15	1,306	842	17	464
Maxwell No. 11	23	1,256	....	....	....
Maxwell No. 12	17	1,267	795	15	472
Scott & Fay:					
W. H. Watrous No. 1	11	1,334	849	20+	485
W. H. Watrous No. 2	13	1,343	833	18	510
W. H. Watrous No. 3	......	[a]1,319	872	16	447
W. H. Watrous No. 4	10	1,376	889	19	487
W. H. Watrous No. 5	14	1,348	824	11	524
W. H. Watrous No. 6	7	1,370	903	17	467
W. H. Watrous No. 7	12	1,379	872	18	507
W. H. Watrous No. 8	8	1,425	932	18	493
W. H. Watrous No. 9	......	[a]1,441	947	15	494
W. H. Watrous No. 10	6	1,410	939	18	471

[a] Elevations furnished by owners.

Elevations of wells of the Atwell sand, including depth, thickness, and elevation of the producing sand—Continued.

Company and well.	No. on map, Pl. XXXIX.	Elevation of well.	Depth to top of sand.	Thickness of sand.	Elevation of sand.
Scott & Fay—Continued.					
W. H. Watrous No. 11	9	1,343	874	20	469
C. H. Watrous No. 1	....	[a]1,440	978	12	462
C. H. Watrous No. 2	5	1,416	954	18	462
C. H. Watrous No. 3	....	[a]1,410	980	20	430
C. H. Watrous No. 4	....	[a]1,438	1,028	22	410
C. H. Watrous No. 5	1	1,502	1,063	20	439
C. H. Watrous No. 6	4	1,443	981	18	462
C. H. Watrous No. 7	3	1,459	1,002	18	457
C. H. Watrous No. 8	2	1,465	1,020	18	445
Knoxville Oil and Gas Co.:					
Knoxville No. 1	58	1,364	871	21	493
Knoxville No. 2	61	1,377	872	21	505
Knoxville No. 3	62	1,377	....	....	....
Knoxville No. 4	59	1,347	841	24	506
Knoxville No. 5	60	1,347	836	21	511

[a] Elevations furnished by owners.

NOTE.—All figures except elevations are based on data furnished by the individual operators.

Elevations of wells of the "Blossburg formation," including depth and elevation of top of formation and of "pay streak," and depths of wells.

Company and well.	No. on map, Pl. XXXIX	Elevation of well.	Depth to formation.	Elevation of top of formation.	Depth to pay streak.	Elevation of pay streak.	Depth of well.
Blossburg and Gaines Oil and Gas Co.:							
Blossburg No. 1	......	....	....	....	....	....	1,320
Blossburg No. 2	......	1,320	557	763	....	....	639
Blossburg No. 3	73	....	632	....	667	....	684
Blossburg No. 4	74	1,334	548	786	660	674	790
Blossburg No. 5	75	1,314	644	670	644	670	1,011
Blossburg No. 6	76	1,275	581	694	600	675	670
Blossburg No. 7	77	1,263	584	679	605	658	796
Blossburg No. 8	78	1,256	585	671	611	645	611
Blossburg No. 9	84	1,235	576	659	600	635	605
Blossburg No. 10	83	1,322	676	646	705	617	800
Blossburg No. 11	82	1,342	730	612	790	552	821
Blossburg No. 12	81	1,400	755	645	890	510	906
Blossburg No. 13	80	1,382	....	....	....	....	......

Elevations of wells of the "Blossburg formation," including depth and elevation of top of formation and of "pay streak," and depths of wells—Continued.

Company and well.	No. on map, Pl. XXXIX	Elevation of well.	Depth to formation.	Elevation of top of formation.	Depth to pay streak.	Elevation of pay streak.	Depth of well.
Wellsboro Oil and Gas Co.:							
Wellsboro No. 1	63	1,251	561	690	566	685	575
Wellsboro No. 2	64	1,250	567	683	589	661	590
Wellsboro No. 3	65	1,220	545	675	564	656	565
Wellsboro No. 4	66	1,216			791	425	792
Wellsboro No. 5	67	1,217	544	673	559	658	714
Wellsboro No. 6	68	1,218	568	650	714	504	755
Wellsboro No. 7	69	1,217	521	696	553	664	729
Wellsboro No. 8	70	1,217	542	675	553	664	720
Wellsboro No. 9	71	1,245	544	701	564+	681	600
Wellsboro No. 10			508		545+		725
Billings Oil and Gas Co.							
Billings No. 1	88	1,301	645	656			800
Billings No. 2	87	1,338	701	637			827
Billings No. 3	86	1,372	710	662			846
Billings No. 4	90	1,319	676	643	701	618	800
Billings No. 5	85	1,426	800	626	907	519	1,015

NOTE.—All figures except elevations are based on data furnished by the individual operators.

CHARACTERS OF THE OIL-PRODUCING SANDS.

ATWELL SAND.

Wells sunk west of the Scott & Fay No. 5, on the C. H. Watrous lot (1 on map) at the western limits of the pool, and east of the Knoxville wells Nos. 3 and 5 (62 and 60 on map) at the eastern limits of the field, have failed to obtain oil. Likewise wells drilled at short intervals both to the north and to the south of the producing wells along the Atwell sand have been unsuccessful. The limits of the productive portion of the sand can be considered, therefore, as fairly well defined.

Throughout the length of the productive belt, a distance of nearly 2 miles, the Atwell sand has been found to be a persistent bed of somewhat uniform character. Its thickness, as reported by the drillers, varies from 12 to 24 feet, but it is usually 16 to 20 feet thick, with an average of about 18 feet along the center of the producing belt. In general it is believed to become thinner toward the south and the east. The supposed representative of the Atwell sand in the wells of the Wellsboro Oil and Gas Company a mile east of the limits of the Watrous pool is reported to have a thickness of only 5 feet in some instances.

There is, at the same time, a general change in the character of the sand eastward from its western limit. The change is one of relative coarseness and toughness and of color. There is in general a gradual decrease in the size of the individual sand grains and an increase in the toughness of the sand as the eastern limit of the pool is approached. At the same time the color of the sand becomes gradually lighter, the deep brown, almost black color characteristic of the western portion of the pool gradually changing to a lighter and more grayish shade of brown as the eastern limit of the field is approached.

The question whether the oil in the Atwell sand is to be considered as occurring in a single pool or whether it occurs in a number of more or less disconnected pools, can not be answered with absolute certainty. The almost uniform success of wells sunk to this sand and the similarity of the character of the sand in the different portions of the field point strongly to the continuity of the pool. On the other hand, the wells, even where sunk at somewhat close intervals, have not usually seriously affected one another's production, each well going through the same succession of a comparatively high initial flow, followed first by rapidly decreasing and then by slowly decreasing flows. It is probable, however, that the independence of one another manifested by the wells is due to the fineness of the texture of the sand rather than to a lack of continuity of the pool. Under such conditions it seems likely that the time between the drilling of the wells is too short for an equilibrium of conditions to be established in the interior of the sand, but that if the time were greater conditions more nearly similar would be established throughout the pool. But even sandstones which are apparently most homogeneous are characterized by small differences in texture or structure, and would, therefore, give up the contained oil at different rates. It seems, on the whole, that the facts warrant the conclusion that the oil of the Atwell sand belongs to a single pool, and that the observed differences in rate and amount of flow are due to differences in the fineness and porosity of the sandstone, taken in connection with the position of the well in reference to the structural limits of the pool.

The Atwell sand is a fine-grained, very dark-brown or almost black sandstone, and is spoken of by the driller as a black sand. The fragments brought up by the bailer, or thrown out in shooting the well, show a finely granular and sometimes distinctly banded texture. The dark-brown color is due to the presence of some solid hydrocarbon compound, presumably largely an impure paraffin, which has separated out from the oil contained in the rock. The odor of petroleum is distinctly noticeable when the sand is first taken from the well, and, on heating, a strong odor of the burning oil and the solid hydrocarbon is obtained, the sand at the same time losing its brown color and changing to a dull gray, tinged with the red oxide of iron.

The lower portion of the sand is usually finer, more shaly, and sometimes carries the calcareous fragments of fossil shells. The formation, if exposed at the surface, would appear as a fine-grained, somewhat uniform buff or brown sandstone, merging into shaly sandstone and shale.

Under the microscope the sand appears to be made up mainly of rather fine and distinctly angular quartz grains. The pores are small and are not at all noticeable. In fact, if it were not for the dark patches and masses of the solid hydrocarbons which occupy such pores, it would be almost impossible to detect their existence. This fineness in texture and the lack of extensive open spaces between the grains is an extremely important factor from an economic standpoint. While oil from such sands is given up with great slowness, there may be, nevertheless, considerable quantities stored in the rock, and wells deriving their supplies from it are likely to be long lived. The appearance of the Atwell sand and its included paraffin, as viewed in thin section under the microscope, is shown in Pl. XL, *A*. The enlargement is about 25 diameters.

The Atwell sand belongs to the "Black sand" group of the oil drillers and is Devonian in age. In its general characters it closely resembles the sands of the Bradford field of Pennsylvania and the Allegany field of New York. It possesses the same general color, the same prevailing fine texture, the same homogeneity throughout its lateral extent, the same constancy of thickness, and the same slow but steady rate of flow that characterize the two important fields mentioned. The principal differences are a slight difference in thickness, a difference in geologic position, and a wide difference in the area of the fields. The question of the geologic position will be considered under the discussion of the geology of the oil field.

"BLOSSBURG FORMATION."

The term "Blossburg formation" has been applied by the drillers to the source of supply of the oil of the wells of the Manhattan group, 1 mile east of Gaines. It is not a single definite bed of sandstone, as in the case of the Atwell sand, but is made up of a series of alternating sands, shales, and shaly limestones, of which certain of the more sandy members have produced oil. The principal producing streak is sometimes known as the Sweeney sand. Stratigraphically the top of the "Blossburg formation," though somewhat variable, is about 200 feet above the horizon of the Atwell sand. The limits of the productive portion of the formation, as defined by its wells, have been given on pages 581–582.

The "Blossburg formation" is not nearly so uniformly productive throughout its area as the Atwell sand. The variation in the production of adjacent wells is often very great, and appears to indicate that their supplies are drawn from more or less distinct pools. On the other hand, there have been a number of instances where the flows of old wells have been greatly reduced, or even stopped, by the opening of new wells. Thus Blossburg No. 3 started off with a production of 500 barrels a day, and was giving 100 barrels a day when Blossburg No. 4 penetrated the "pay streak," a few hundred feet away, whereupon the flow of No. 3 ceased and the well was abandoned. Blossburg No. 4 is known locally as the "big gusher," and gave 2,100 barrels a day at the start. The flows of the Blossburg wells are also said to have been adversely affected by the Wellsboro wells, which are situated a little farther down the dip slope to the north. It is claimed that in general the flow of the wells to the south and west are adversely affected by the wells to the north and east.

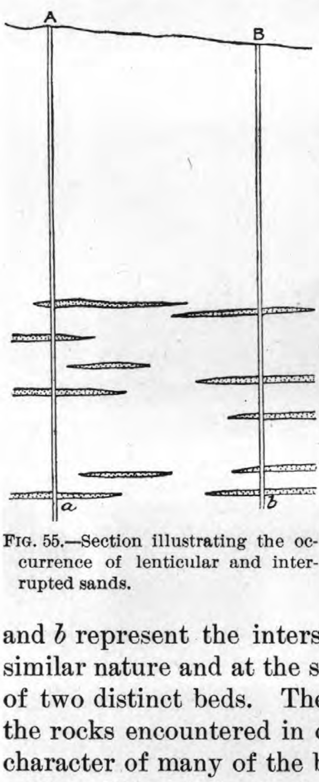


FIG. 55.—Section illustrating the occurrence of lenticular and interrupted sands.

In some cases the flows from what is apparently the same level have been greatly different in adjacent wells, and seem to indicate that independent sources of flow may occur at the same horizon. The probable conditions in such instances are shown in fig. 55, which represents a "formation" similar to the Blossburg, and made up of a number of thin, flat sheets or lenses of comparatively small area, interstratified with shales or shaly sandstones and limestones too impervious for the passage of oil through their mass. In the figure, *a* and *b* represent the intersection of the wells A and B with sands of a similar nature and at the same level, but which are, nevertheless, parts of two distinct beds. The cause of the difference in the sequence of the rocks encountered in different wells is explained by the lenticular character of many of the beds, as shown in the figure.

The wide variation in the flows of adjacent wells and the suddenness with which the oil was expelled in the case of the larger wells, taken in connection with the apparent dropping of the tools in some instances during drilling, has led to the belief among certain of the oil men that the oil occurs in crevices or open spaces in the rock. In so far as the rather marked bedding planes of the rock furnish a passage for the oil they may be considered as crevices, although there is almost no possibility of an actual open space existing between the layers of the

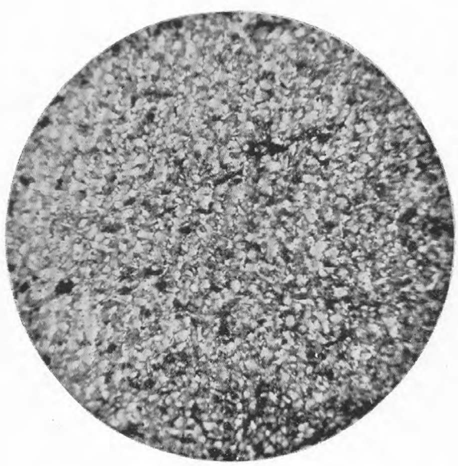
PLATE XL.

PLATE XL.

A. Section of Atwell sand. The light-colored angular grains are of quartz. The irregular dark patches are solid hydrocarbons deposited from the oil while it occupied the pores of the sandstone. Enlarged about 25 diameters.

B. Section of one of the sands of the "Blossburg formation." Sample taken from the level of highest production (660 feet from surface) in well No. 4 of Blossburg and Gaines Oil and Gas Company. The well produced 2,100 barrels a day from this level. The white and light-colored grains are of finely divided and highly angular quartz. The dark patches are solid hydrocarbons occupying the pores of the sandstone. Enlarged about 25 diameters.

(A)



(B)

APPEARANCE OF OIL SANDS UNDER THE MICROSCOPE.

A, Atwell sand; *B*, sand of "Blossburg formation."

gently northward-sloping rocks. Joint planes cutting the rocks in approximately vertical directions may possibly occur. Jointing, however, is not prominent at the surface, and the general absence of meteoric waters at depths below 400 or 500 feet seems to indicate that jointing does not extend beyond these depths. Much of the rock of the "Blossburg formation" is calcareous, and pockets or crevices may be imagined as resulting from solution. The absence of circulating water at these depths, however, makes the existence of such solution cavities very improbable. A general examination of the rocks of the adjoining region northward to the New York line disclosed no evidence of dynamic disturbance beyond a gentle folding of the rocks, and no evidences of anything which could be considered of the nature of a crevice except the ordinary bedding planes and joints. It seems probable that the apparent dropping of the tools in drilling is due to the sudden change from a hard rock, such as a sandstone, to a very soft rock, such as certain of the shales, into which the drill might penetrate for some distance at a single blow. It is possible that the catching of the drill on some irregularity of the yet imperfectly formed hole very near the bottom on relowering the drill at the resetting of the screw, and its subsequent dropping to the original bottom of the hole, may give rise to the impression of a crevice. This is especially likely where no mark of the position of the screw clamps at the previous setting is retained on the rope.

To the oil men one of the most interesting of the problems connected with the oil supply from a "formation" like the Blossburg is the size of the individual pools. It is a problem, however, which can almost never be solved with any great degree of accuracy, especially in the smaller pools, where the only direct information is obtained from a single well. In such a case the volume of the oil and the thickness of the producing sand are known, but, except when delimited by surrounding dry holes, a single well shows nothing of the lateral extent of the pool; neither does it give any except very local evidence of the variations in texture or thickness of the oil-bearing sand, both of which are points of the greatest importance.

In some instances, as in the case of the big Blossburg "gusher," it is possible to fix a probable minimum limit. This well started off with a flow of 2,100 barrels a day, from which it slowly fell off to 30 barrels a day in about two months. Its total product can be safely stated to have been at least 30,000 barrels, which in bulk would occupy a space of 4,763 cubic yards. The oil, however, did not occur in an open space, but is assumed to have been dispersed through the pores of a very fine-grained sandstone. Tests made on sandstones show that they will absorb amounts varying from almost nothing, in the case of the fine, closely cemented sandstones, to 10 or 15 per cent of their bulk in the looser and more porous sandstones. The oil sand in the Blossburg well under discussion would probably hold not more than 1 per cent of its bulk, and could certainly not hold more than 5 per cent, which is the amount here assumed in calculating the minimum size of the pool. On this supposition the oil would be distributed through some 95,256 cubic yards of the sandstone. Assuming the aggregate thickness of the sandstones containing the oil to average 9 feet, the pool would have an area of 31,752 square yards, or a little less than 7 acres.

In their physical characters the sands of the "Blossburg formation" do not differ greatly from the Atwell sand, all of them being fine grained and of a dark color. The Blossburg sands, however, are less uniform than the Atwell, both in color and in texture. As a rule they are lighter in color, more shaly in texture, and more often associated with calcareous shales and thin limestones. In its broken character it somewhat resembles the well-known Venango group of sands, which have been the source of many highly productive wells in the western portion of the State. The character of the production was likewise similar, both the Venango sands and the Blossburg giving rise to strong "gushers," which in both fields soon declined or even failed entirely, being in this respect in marked contrast to the Bradford and Allegany fields and the adjacent Watrous pool, the wells of which in every case maintain their flow with greater uniformity and for much longer periods. In size the productive area of the "Blossburg formation" is insignificant compared with the areas of the three large fields mentioned. (See Pl. XXXVI.)

Under the microscope the Blossburg sands are seen to be composed almost entirely of exceedingly fine and exceptionally angular quartz grains, among which are scattered the calcareous fragments of fossil shells. The laminar arrangement, due to stratification, is easily recognized in some specimens. There is very little argillaceous material present, but the sand is characterized by the presence of considérable amounts of a solid bituminous material, supposed to be paraffin, which presumably represents solids deposited from the oil during its occupation of the pores of the rock. It is distributed throughout almost the whole of the material examined, usually appearing as a greenish or brownish stain, but in places where the pores were apparently larger occurring in opaque spots and masses of some size.

In some of the darker specimens the black bituminous matter was found to be present in large amounts, some portions being opaque even in thin sections. As in the case of the Atwell sand, strong organic fumes were given off on heating and the sand became whitened. The occurrence of bituminous matter in portions of the sand which are now barren of oil is of interest as showing the former presence of the latter in considerable quantities. It may be conceived that by the deposition of such solid hydrocarbons the pores of an originally good oil sand may become so clogged that it can no longer act as a reservoir for oil.

PRODUCTION.

CHARACTER OF THE OIL.

There is no difference in the quality of the oil obtained from the Atwell sand and that obtained from the "Blossburg formation." In both cases the oil is of a good amber color, has a gravity of 44° (Baumé), and next to the Tiona oil of Warren County, Pa., is probably one of the best oils in the country. It sells in the market for 15 cents less per barrel than the Tiona oil, but commands a better price than any oil outside the Pennsylvania fields.

In addition to the illuminating oil, slight amounts of a heavy lubricating oil were encountered in the "Blossburg formation," but it did not occur in paying quantities and was cased off in most of the wells in which it was found. A black, waxy, bituminous substance known as paraffin was pumped in very small amounts from certain of the wells of the "Blossburg formation."

PRODUCTION AND DISPOSITION OF THE OIL.

In the wells in the Atwell sand the oil enters very slowly and rarely has risen any great distance in the well. Pumping has been finally resorted to in every case, though in a few wells the oil flowed slowly at the start without pumping. In many of the wells of the "Blossburg formation" the oil rose to the surface, sometimes with considerable force, as in the case of the "big gusher" (Blossburg No. 4).

The amount of oil produced by single wells in the first twenty-four hours has varied from 2 or 3 barrels up to 2,100 barrels, the low flows being from the Atwell sand and the high flows from the restricted but powerful local pools of the "Blossburg formation." In the accompanying tables the production at start is given for nearly all of the individual wells, the amounts being based upon the statements of the officers of the respective companies. Figures for the initial production of the Scott & Fay wells can not be given, but they are probably not greatly lower than the average figures for other wells near the limits of the pool.

Production of wells of the Gaines oil field, as reported by the individual operators.

Well.	Production at start.
South Penn Oil Co. (wells in Atwell sand):	*Barrels per diem.*
Atwell No. 1	10
Atwell No. 2	20
Atwell No. 3	10
Atwell No. 4	35
Atwell No. 5	35
Atwell No. 6	15
Atwell No. 7	25
Atwell No. 8	25
Atwell No. 10	40
Atwell No. 11	25
Atwell No. 13	20
Dimmick No. 1	50
Dimmick No. 3	30
Dimmick No. 4	30
Dimmick No. 5	35
Dimmick No. 6	20
Dimmick No. 8	35
Dimmick No. 9	8
Dimmick No. 10	8
Dimmick No. 11	25
Legal No. 1	15
Legal No. 2	30
Legal No. 3	20
Legal No. 4	15
Legal No. 5	10
Legal No. 6	25
Legal No. 7	11
Knoxville Oil and Gas Co. (wells in Atwell sand):	
Knoxville No. 1	55
Knoxville No. 4	35
Maxwell Oil Co. (wells in Atwell sand):	
Maxwell No. 2	20
Maxwell No. 3	75
Maxwell No. 4	25
Maxwell No. 5	30
Maxwell Oil Co. (wells in Atwell sand)—Continued:	*Barrels per diem.*
Maxwell No. 6	15
Maxwell No. 7	40
Maxwell No. 8	3
Maxwell No. 9	50
Maxwell No. 10	6
Blossburg and Gaines Oil and Gas Co. (wells in Blossburg formation):	
Blossburg No. 2	6
Blossburg No. 3	500
Blossburg No. 4	2,100
Blossburg No. 5	230
Blossburg No. 6	200
Blossburg No. 7	100
Blossburg No. 8	100
Blossburg No. 9	30
Blossburg No. 10	100
Blossburg No. 11	60
Blossburg No. 12	60
Wellsboro Oil and Gas Co. (wells in Blossburg formation):	
Wellsboro No. 1	56
Wellsboro No. 2	22
Wellsboro No. 3	25
Wellsboro No. 4	30
Wellsboro No. 5	5
Wellsboro No. 6	15
Wellsboro No. 7	150
Wellsboro No. 8	200
Wellsboro No. 9	250
Wellsboro No. 10	100
Billings Oil and Gas Co. (wells in Blossburg formation):	
Billings No. 1	140
Billings No. 2	500
Billings No. 3	60
Billings No. 4	20

Production of wells of the Gaines oil field, as reported by the individual operators—Cont'd.

Well.	Production at end of 10 days.	Well.	Production at end of 10 days.
Scott & Fay (wells in Atwell sand):	*Barrels per diem.*	Scott & Fay (wells in Atwell sand)—Continued.	*Barrels per diem.*
W. H. Watrous No. 1	10	W. H. Watrous No. 10	4
W. H. Watrous No. 2	10	W. H. Watrous No. 11	10
W. H. Watrous No. 3	10	C. H. Watrous No. 1	1
W. H. Watrous No. 4	5	C. H. Watrous No. 2	4
W. H. Watrous No. 5	2	C. H. Watrous No. 5	2
W. H. Watrous No. 6	5	C. H. Watrous No. 6	2
W. H. Watrous No. 7	3	C. H. Watrous No. 7	2
W. H. Watrous No. 8	6	C. H. Watrous No. 8	2
W. H. Watrous No. 9	2		

Summary of production at start, as reported by individual operators.

Company.	Producing sand.	Number of wells reporting.	Production at start.		
			Maximum.	Minimum.	Average.
			Barrels per diem.	*Barrels per diem.*	*Barrels per diem.*
South Penn Oil Co.:					
"Legal" purchase	Atwell	6	30	10	19
Atwell lease	do	11	40	10	24
Dimmick lease	do	9	50	8	27
Knoxville Oil and Gas Co	do	5	55	?	30
Maxwell Oil Co	do	9	75	3	27
Scott & Fay (estimated)	do	14	20	2	10
Blossburg and Gaines Oil and Gas Co.	Blossburg	11	2,100	6	317
Wellsboro Oil and Gas Co	do	10	250	5	85
Billings Oil and Gas Co	do	4	500	20	180

The tables bring out strongly the differences in initial flows of the wells of the two formations, showing the average flows from the "Blossburg formation" to be from three to ten times as great as those from the Atwell sand. But notwithstanding the lower initial production of the wells of the Atwell sand, the greater slowness with which the supply decreases makes it certain that the longer life of the wells will more than compensate for the small daily production. After the first ten days the falling off of the production is extremely slow, and at the end of a year the flow is usually 50 per cent or more of that at the end of the first ten days. As has been already stated, few of the wells of the Atwell sand have been exhausted, while in the "Blossburg formation" a large proportion of the wells, especially where the initial flow was large, have ceased to produce within six months or a year.

In the wells in the Atwell sand the oil reaches the surface free from water. In the wells of the "Blossburg formation" it reaches the surface either as approximately clear oil, as in the case of a few wells, or mixed with salt water, as in the case of the larger number of the wells. When fresh water is encountered it is cased off, but the salt water is sometimes so intimately associated with the oil that it is impossible to case it off. In such wells the mixture is pumped into a receiving tank, from the bottom of which the water is siphoned off, while the oil at the surface passes into another tank where it is stored, awaiting transportation.

The oil from the Gaines field is disposed of in two ways. The larger portion, controlled by the South Penn Oil Company, is conducted by pipe to the company's 15,000-barrel tanks on the Atwell property. From here it is carried nearly due south by a 3-inch pipe to the trunk of the Tide Water Pipe Line, some 16 miles from Gaines. Other companies which dispose of their oil through the South Penn Oil Company are the Knoxville Oil and Gas Company, the Blossburg and Gaines Oil and Gas Company, the Billings Oil and Gas Company, and the Hovey Oil Company. Other companies dispose of their oil to the John Ellis Company, of Warren, Pa., by which it is removed in tank cars.

METHODS OF INCREASING THE PRODUCTION OF OIL.

When a well penetrates a sand like the Atwell, the oil ordinarily enters the hole rather slowly, partly because of the low hydrostatic or gas pressure, partly on account of the fineness of the rock texture, and partly because of the small surface exposed in the walls of the well from which the oil can enter. It is evident that anything which increases the size of the surface from which oil can enter the well or which tends to open the pores of the rock, thereby increasing the ease with which the oil passes through it, will tend to produce an increased flow.

Both of these results are produced by the process known as shooting, which consists in the explosion of heavy charges of nitroglycerin at points where the sandstone seems to be most likely to produce a good flow. The charge, incased in metallic canisters, is carefully lowered to the desired spot and is exploded by the concussion of an iron bar known as the "go-devil," which is allowed to fall upon it. The explosion is made evident on the surface by a heavy but dull roar, accompanied usually by a powerful jet of smoke, water, oil, gas, and stones, which often rise with great force high above the derrick. Pl. XLI shows one of the Knoxville wells at the moment following the explosion of the charge.

The effect of the explosion is to completely shatter the rock for a radius of several feet and to loosen the sandstone and open its pores for a considerably greater distance. The well is, of course, more or less clogged by the operation, but is usually cleared out with the drill without difficulty.

With the exception of the "gushers" of the "Blossburg formation" the wells of the Gaines field are usually shot before pumping is begun, and it is therefore difficult to obtain reliable figures as to the increase of production brought about by the explosion. The oil men consider that the production in the Atwell sand may thereby be increased as much as ten times.

The manner in which the increase of production is brought about can be more clearly explained by reference to figs. 56 and 57. Fig. 56 represents a well penetrating an oil sand lying between two shales and assumed to be oil bearing throughout, but with a maximum flow in the coarser layer at A. All oil entering the well must work its way slowly through the rock, passing into it through the walls. If the sandstone is 10 feet thick and the hole 6 inches in diameter, there will be 16 square feet of surface through which the oil can enter. Fig. 57 represents the conditions after the explosion of a very small charge at A, on the moderate assumption that the rock within a radius of $2\frac{1}{2}$ feet from this point has been shattered and that the sand has been loosened everywhere within a radius of 5 feet. The shattered portion of the rock will offer practically no resistance to the entrance of oil into the well, the actual surface from which it now enters being the surface inclosing the shattered portion. This, in the case assumed, would be approximately spherical in form and would have an area of about 79 square feet, or some five times that of the original surface of the walls of the well. The entrance of the oil would be further facilitated to a considerable extent by the opening of the pores, due to the loosening of the component grains of the sandstone by the shock of the explosion.

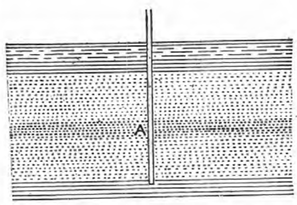


FIG. 56.—Section showing an oil sand in an undisturbed condition.

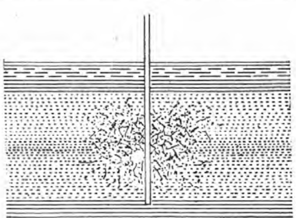


FIG. 57.—Section of an oil sand after shooting.

In the Gaines region the wells below a depth of 200 to 500 feet are free from waters which have penetrated from the surface, the lower portions of the wells being drilled dry. The entrance of oil into a well can not, therefore, be due to hydrostatic pressure of such waters, as has been claimed for other regions, but is apparently due to the pressure of the associated gas, or to the weight of the oil itself. The entrance of the oil is always opposed by an atmospheric pressure of approximately 15 pounds to the square inch. Anything tending to decrease this atmospheric pressure will naturally tend to increase the rate of flow of the oil.

It is on this principle that the so-called "gas pumps" work. By means of these pumps the air or gas of the well tube is exhausted as much as possible, the pressure in cases being reduced from 15 pounds to within 2 or 3 pounds of absolute vacuum. Under such conditions the oil enters the well with considerably greater facility.

The gas pump has been applied to a number of the wells of the "Blossburg formation," but did not increase the flow or prolong the production to any considerable extent. The local character of the pools furnishing the supply makes it doubtful if the use of the gas pump in the wells of the "Blossburg formation" will prove to be a success, but it is probable that its use in the wells of the Atwell sand would give more satisfactory results.

The question whether the total life production of a well is increased by shooting or by the use of the gas pump is one which depends upon local conditions. If a pool is small enough, so that all parts come within the influence of the wells under ordinary conditions, the total supply will not be increased either by shooting or by the use of the gas pump. If, however, the oil formation is extensive, there will be a probable limit beyond which the pressure of its associated gas or the weight of the oil itself will be insufficient to cause it to flow toward the well in opposition to the ordinary atmospheric pressure. The removal of this atmospheric pressure would, however, allow oil to reach the well from distances greater than would ordinarily be the case, and the total production would probably be increased.

In the case of shooting the wells, the total production of the well is probably increased only to the extent that the sphere of influence of the well is enlarged by the shattering and loosening of the rock.

In shooting in the Gaines oil field the charge is approximately proportional to the fineness of the rock texture, the charges varying from 20 to 100 quarts. Since the Atwell sand is finer and denser in the eastern portion and also to a lesser extent at the western extremity, the charges here used are greater than in the central portion of the pool. This relation is brought out by the following table, which shows the maximum, minimum, and average shots for the three groups of wells which, beginning at the top, are, respectively, in the eastern, central, and western portions of the pool:

Amounts of nitroglycerin used in shooting.

Wells.	Number of wells.	Maximum.	Minimum.	Average.
		Quarts.	*Quarts.*	*Quarts.*
Atwell	13	100	30	72
Dimmick	12	100	20	49
Scott & Fay	18	90	40	61

VIEW OF THE "SHOOTING" OF ONE OF THE KNOXVILLE WELLS.

ITEMS AFFECTING COST OF WELLS.

The majority of the wells of the Gaines oil field have been sunk by contract. The rocks encountered in drilling are usually comparatively soft, and consist largely of shales, shaly sandstones, and some shaly limestone. The sandstones which are encountered are seldom of any great thickness, and are usually of only moderate hardness and toughness. The rate of drilling is somewhat variable, but 70 feet or more has frequently been drilled in a day of twenty-four hours.

The depth to the sands depends to a considerable extent upon the topography and position of the site of the well relative to the dip of the bed. The depth to the Atwell sand in the wells of the Watrous pool varies from 705 to 1,063 feet, while in the wells of the Manhattan pool the depths to the pay streaks of the "Blossburg formation" vary from 545 to 907 feet. The depths to the producing sand or to the pay streaks of the individual wells are given in the table on pages 588–591.

The average contract price paid by the South Penn Oil Company for drilling is said to be 65 cents per foot, but the cost to the small operator is likely to be somewhat greater. Other items of expense include the cost of drive pipe, casing, and nitroglycerin. The maximum, minimum, and average amounts of each are given in the accompanying table for each group of wells:

Drive pipe, casing, and nitroglycerin required in the sinking and shooting of the wells of the Gaines oil field.

Group of wells.	Producing sand.	Number of wells.	Drive pipe.			Casing.			Nitroglycerin.		
			Max.	Min.	Av.	Max.	Min.	Av.	Max.	Min.	Av.
South Penn Oil Company:			*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Qts.*	*Qts.*	*Qts.*
Atwell lease	Atwell	13	42	12	25	456	273	355	100	30	72
Dimmick lease	do	12	42	15	26	443	344	385	100	20	49
Legal Oil Company purchase.	do	7	37	12	27	443	411	425	(?)	(?)	(?)
Scott & Fay	do	19	138	52	112	723	372	434	90	40	61
Maxwell Oil Company.	do	11	35	17	23	663	367	457	60	40	50
Knoxville Oil and Gas Company.	do	5	123	74	97	334	321	329	(?)	(?)	(?)
Blossburg and Gaines Oil and Gas Company.	Blossburg	12	84	22	54				Usually not shot.		
Wellsboro Oil and Gas Company.	do	10	48	20	32	440	328	565			
Billings Oil and Gas Company.	do	5	95	43	67						

OCCURRENCE OF NATURAL GAS.

The oil of the wells of the Gaines field is almost invariably associated with greater or less quantities of gas. In the "Blossburg formation" the gas is often intimately associated with the oil, being incorporated with it in much the same manner that carbon-dioxide gas is incorporated in so-called "soda water." It is only when under strong pressure, as in reservoirs of limited size, that such a mixture exists, and when finally released by the tapping of the pool by a well the mixture rises to the surface as a foaming mass of oil and gas. Such was notably the case at the striking of the "big gusher" (Blossburg No. 4); so great was the pressure of the mixture of oil and gas that it burst through a bed of "shell rock" a foot or more in thickness.

In the Atwell sand, where the oil is not confined to limited pools but is distributed throughout a large mass of rock, the gas is much less thoroughly incorporated with the oil and is usually found separated from it and lying in higher portions of the rock.

The fact that in the wells of the "Blossburg formation" the gas is to a greater or less extent incorporated with the oil and does not occupy independent reservoirs explains the cause of the failure of the gas which occurs as soon as the oil ceases to flow. In the wells of the Atwell sand, on the other hand, the supply remains nearly uniform for a considerable length of time. The gas is not confined to any particular horizon in the wells of either the Atwell sand or the "Blossburg formation," but is encountered at various horizons, both above and below the producing sands.

Local gas pools have also been encountered outside the limits of the Gaines field. In some instances the pressure has been great and the gas has escaped control. One or more derricks have been destroyed by the igniting of the gas that escaped under high pressure from pools which were unexpectedly encountered at times when the drillers were unprepared.

The well-known general rule that when salt water, oil, and gas are present in the same rock they exhibit a tendency to arrange themselves according to gravity in the order named applies in a general way to the oil-bearing formations of the Gaines field. It may be said that north of the productive belt, where the wells strike the producing formation farther down the dip slope, the production is mainly salt water, while the wells to the south of the productive belt produce mainly gas. The occurrence of salt water, oil, and gas at different horizons, however, gives rise to many apparent exceptions to this rule, though at any single horizon the rule generally holds.

Although the supply of gas from the wells of the Atwell sand is fairly constant, the amount is small, and is barely sufficient to furnish fuel for the boilers required in pumping. Pipes have been laid, however, to a few buildings in Gaines and Watrous, and small quantities are disposed of by sale, though the supply is cut off during pumping hours. The gas obtained from the "Blossburg formation" is too small in amount to be of use either for fuel or for illuminating purposes.

GEOLOGY OF THE OIL FIELD.

THE GEOLOGIC PROVINCE.

The Gaines oil field is located in the westernmost division of what is known geologically as the Appalachian province. This province has been subdivided into three grand divisions, which in Pennsylvania are characterized by the Appalachian Mountains on the east, the Appalachian Valley in the central portion, and the Allegheny Plateau on the west.

In Pennsylvania the Appalachian Mountains are represented by the rounded and soil-covered South Mountain and by the ridges reaching from near Reading to Easton. (See Pl. XXXVI). The Appalachian Valley is characterized by the occurrence of long, straight, and conspicuous ridges alternating with well-marked valleys, and is a valley only in the sense that it is bounded by more pronounced highlands. West of the Allegheny Front, constituting the western boundary of the Appalachian Valley, lies the Allegheny Plateau, which, as the name signifies, partakes of the nature of a general upland, trenched, it is true, by deep and gorge-like valleys, but lacking the marked ridges characterizing the previous division.

Geologically, the three divisions of the Appalachian province are likewise quite distinct. The Appalachian Mountains of the eastern division are characterized by the occurrence of many more or less crystalline rocks, representing on one hand altered sedimentary deposits and on the other igneous rocks, such as granite, diabase, etc., which have solidified from a molten condition. The Appalachian Valley, constituting the central division of the province, is characterized, on the other hand, by the absence of crystalline rocks, their place being taken by a great thickness of sedimentary strata which have been compressed into long, straight, and parallel folds, and which have given rise by erosion to the conspicuous ridges and valleys mentioned. The division enters Pennsylvania in Bedford County and the counties immediately to the east, and extends northward with a gradually increasing eastward trend to the region of Williamsport, Lycoming County, beyond which the folds gradually become less pronounced and the ridges less prominent. In the Allegheny Plateau the folds are usually broad, open, and gentle, and are frequently of considerable length, following with great regularity along straight or curved lines parallel with the Allegheny Front. With the exception of Laurel and Chestnut ridges, in the southern portion of the State, the folds are seldom directly represented by ridges or other topographic features. In proceeding westward and northwestward the folding becomes more gentle and open, finally merging into the monoclinal or very gently undulating structure of northwestern Pennsylvania and eastern Ohio. The

Gaines oil field, as has been stated, lies in this gently folded division, its distance measured across the strike of the folds being some 40 miles northwest of the Allegheny Front.

DESCRIPTION OF FORMATIONS.

The deep cutting of the streams, taken in connection with the moderate folding of the beds, is sufficient to expose to view in the vicinity of the oil field a thickness of more than 2,000 feet of rocks of Devonian and Carboniferous age. These exhibit many alternations of sandstone, shale, impure limestones, etc., but they may be so grouped by their lithologic characters as to form five formations, each marked by its own characteristic and distinctive features. In ascending order these lithologic divisions are, respectively, the Chemung, Catskill, Pocono, Mauch Chunk (?), and Pottsville formations. The first two are Devonian and the remainder are Carboniferous in age. Their general character and relative thicknesses are shown graphically in the geologic column, Pl. XLII.

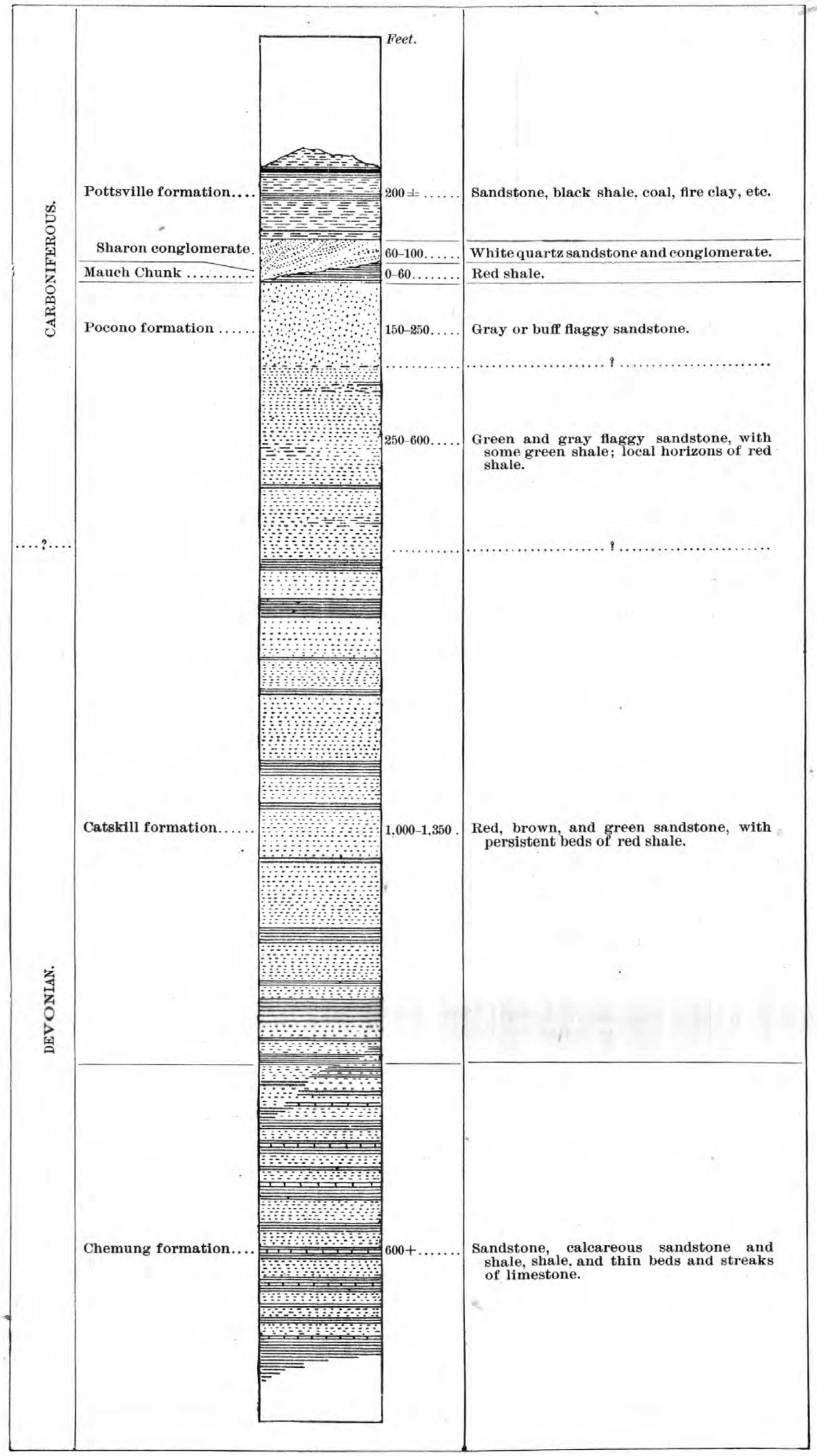
DEVONIAN ROCKS.

CHEMUNG FORMATION.

The name Chemung is here used as a lithologic term and includes the thick series of alternating shales, sandstones, and thin limestones which have as their lower boundary (not exposed in the Gaines region) the bluish shales of the Portage formation, and as their upper boundary the red shales or the red or green sandstones of the Catskill formation. It should be clearly distinguished from the paleontologic Chemung, which includes both the marine fauna of the lithologic Chemung and the fresh- or brackish-water fauna of the overlying Catskill formation.

The Chemung is the formation from which the oil and gas of the Gaines field are obtained, and is the lowest of the formations encountered either at the surface or in the oil wells. Its materials were laid down in the northeastward extension of the great interior sea which in Devonian times occupied the central and southern half of what is now the North American continent.

The formation is made up largely of a series of calcareous and shaly sandstones, alternating with thick beds of soft shale and thin seams of limestone. Gray and greenish gray are ordinarily the predominating colors of both the sandstones and the shales, but when oil is present the sandstones are of a dark-brown, almost black, color, giving rise to the term "Black sands," which has been applied to the producing sands in the Bradford, Allegany, and Gaines fields. The calcareous sandstone is of the type which has come to be considered as especially characteristic of the Chemung, namely, a somewhat coarse, friable



COLUMNAR SECTION OF THE GAINES OIL REGION.

Scale: 1 inch = 400 feet.

sandstone, crowded with open cavities left by the solution of the fossil shells which it originally contained. Where the Chemung is exposed at the surface, this sandstone sometimes appears to constitute the predominating rock, but this is probably due largely to the fact that it is more resistant to disintegration than the soft and finely laminated shales which the well record (see pp. 583–584) show to constitute the larger portion of the formation. The calcareous sandstones grade on the one hand into typical gray and somewhat flaggy sandstone, and on the other into more or less pure limestones.

The limestones are of two distinct types. The first and most common is a dark bluish gray, almost black, argillaceous limestone, rich in brachiopod fossils, and occurring in beds usually only a few inches in thickness. The second type, which sometimes occurs in beds several feet in thickness, may be of a gray, bluish, or pinkish color, and is composed almost entirely of the fragments of small crinoids, in some instances exhibiting in their arrangement a typical cross-bedded structure.

The general character of the Chemung sedimentary rocks appears to be fairly uniform throughout. Beds of sufficiently distinct lithologic character to admit of tracing if they were continuous are known, but no beds which could be recognized at widely separate points have been seen. This absence of traceable beds adds greatly to the difficulty of working out the geologic structure and of definitely recognizing the majority of beds encountered in drilling. The upper limit of the formation is somewhat imperfectly defined by the horizon of red beds which immediately overlies it.

In the immediate vicinity of the Gaines oil field the Chemung is not exposed. It comes to the surface, however, near the crest of the anticline in the vicinity of Marshfield, some 2 miles south of the Watrous pool, where it is cut to a slight depth by Elk Run. In the next anticline to the north and northeast of Gaines (Pl. XLII), the Chemung constitutes the surface rock throughout a belt varying from 1 to 10 miles in width. At least 1,000 feet of the shales, sandstones, and thin limestones of the formation are here exposed.

The bottom of the lowest bed of red shale, or of the characteristic red or green sandstone of the Catskill type, is here taken as marking the top of the Chemung formation, although overlying the lowest of these Catskill beds there are in cases from 50 to some 200 feet of strata which are lithologically identical with the rocks of the Chemung formation, and which are characterized by the same, though generally less numerous, marine fossils.

CATSKILL FORMATION.

The change from Chemung to Catskill deposits was probably brought about by a slight elevation of the land, resulting in the more or less complete separation of the embayment in which the Catskill deposits of Pennsylvania and New York were laid down from the open interior sea, the salt-water deposits of the Chemung giving place, as attested by ferns, fresh-water lamellibranchs, etc., to the fresh- or brackish-water deposits of the Catskill. The waters at the same time doubtless became much shallower, as indicated by the greatly increased frequency of cross bedding and the occurrence of ripple marks, rain prints, and other shore features.

The time at which the advent of Catskill conditions took place was not the same throughout the extent of the formation, but was earliest in the east and became progressively later as the distance to the west increased. In eastern New York the deposition of Catskill beds began at the close of the Hamilton, and as time elapsed and the conditions became favorable similar beds were deposited farther and farther west. It was not, however, until near or at the close of the Devonian that conditions favorable to the deposition of red beds came into existence in western New York. In the Gaines region the Catskill conditions were inaugurated after 1,000 to 1,500 feet or more of Chemung sediments had been deposited, and continued at least to the close of the Devonian.

The formation in the area under discussion consists of a thick series of practically unfossiliferous gray or green shales and sandstones interspersed at intervals with bright-red shales and red or brown sandstones. The red beds constitute the most characteristic members of the formation, and have come to be considered as the distinctive feature of the Catskill. If the Catskill formation is made to include the interval from the lowest to the highest of the persistent red beds, it is probable that the actual thickness of the red material will not much exceed a third of the whole thickness, the remainder being taken up by the green and gray shales and sandstones. Of these the green sandstone is the most conspicuous. This is largely because of its hardness and its siliceous composition, which causes it to resist erosion and to stand out more conspicuously than the softer portions of the formation. When fresh, it is of a distinct greenish color on the exposed surfaces. It is almost invariably cross bedded, the laminæ of both the sloping and the horizontal layers being unusually thin and perfect. Of the gray and green shales the former predominate and form a very important part of the formation. They are well exposed along the railroad on the north bank of Pine Creek and in the high cliffs bordering the lower portion of Elk Run. Some of the lighter shale beds carry ferns and other plant remains, possibly indicating a fresh-water origin for the beds in which they occur.

The red shales are best developed and most persistent near the base of the series and furnish the basis for the separation of the Catskill from the underlying Chemung. Higher up in the formation the beds of red shale are thinner and apparently less persistent, and above a horizon situated about 1,000 feet above the base are probably to be considered as mainly of the nature of local lenses. In general, it may be said that the thicker and more persistent red beds lie below this line, while only comparatively thin and restricted red beds occur above it. In the absence of paleontologic evidence it is impossible to determine whether the transition from the Catskill to the Pocono should be considered as occurring at the upper limit of these persistent red beds or at some higher horizon in the series.

The Catskill sandstones and shales constitute the surface rocks of the Gaines oil field and the immediate vicinity. The belt, of which these exposures form a part, marks the northern flank of the New Bergen-Wellsboro anticline, and its rocks are exposed at many points along Pine and Marsh creeks as far as Stokesdale. To the north the Catskill beds are exposed along the northern border of the Pine Creek syncline, and at many points along the sides and bottom of the portion of the Cowanesque River above Elkland.

CARBONIFEROUS ROCKS.

POCONO FORMATION.

The change of the deposits from Devonian to Carboniferous in the Gaines region is not marked by any recognizable break. Whether, following the usage of the Second Pennsylvania Geological Survey, the whole of the great mass of greenish-gray sandstones with the included local beds of red shale lying between the persistent red beds and the Mauch Chunk or Pottsville formations is regarded as Pocono, or whether only the upper and possibly lighter portion of the sandstone series is to be so regarded, it is certain that there were no important changes either in the character of the sediments or in the conditions of deposition. There was simply a gradual change from conditions favorable to the deposition of shale to conditions favoring the deposition of sandstones, though shales appear to have been deposited locally throughout nearly the entire vertical range of the Pocono.

On exposed surfaces the sandstones are predominantly of a distinct greenish-gray color. Internally, however, they are of a dirty buff or brown color, distinctly argillaceous, and frequently specked with limonitic spots, probably due to the decomposition of minute crystals of pyrite. On continued exposure to the weather the sandstones seem to lose their greenish tinge, becoming light gray in color, presumably because of the washing away of the finer products of disintegration and decay, leaving only the insoluble quartz showing upon the surface.

Like those of the Catskill formation, the Pocono sandstones are almost invariably cross-bedded, and are characterized by the frequent occurrence of minute mica plates along the lamination planes. In fact, the greenish sandstones of the two formations are so similar that it is impossible to distinguish them by their lithologic characters.

In the upper portion of the Pocono formation, as the term was used by the Pennsylvania survey, there is a thickness of perhaps 100 or 200 feet of a sandstone which sometimes appears to be of a lighter, more gray or buff color than the greenish sandstone forming the mass of the rock between the persistent red beds of the Catskill and the bottom of the Pottsville formation. Whether this is due to an actual difference in composition or simply to the bleaching action of the weather is not clearly established. If it is to be considered as a separate formation of Pocono age, it is quite possible that the green sandstones lying below it will have to be included in the Catskill formation. The fact that red beds of the Catskill type are known to occur locally up to within 150 or 200 feet of the bottom of the Pottsville formation gives some weight to this view. The finding of characteristic fossils in the two sandstone groups would definitely fix their position in the geologic series, but in the absence of such data the question must be left undecided. The upper limit of the Pocono has been purposely omitted in the construction of the geologic column, Pl. XLII, because of this absence of reliable data.

The total thickness of the shale and sandstone series between the Chemung formation and the base of the Pottsville probably varies from 1,600 to 1,700 feet. On the assumption that the uppermost of the persistent red beds marks the transition between the Catskill and Pocono formations, there will be from 600 to 800 feet of Pocono material. If, on the other hand, the upper and lighter sandstone is considered as representing the whole of the Pocono, its thickness must be limited to 150 or 200 feet.

The rocks of the Pocono formation constitute the upper portion of the hills along both sides of Pine Creek in the vicinity of Gaines, though the rocks of the immediate crests of the hills north of the creek belong to a higher formation. Extensions of the same belt occur along the Pine Creek syncline (Pl. XLIII) to beyond the Tioga River on the northeast and to the southwest corner of Potter County. Another belt starts in Hector Township and extends southwestward, finally uniting with the former belt in the southwest portion of Jackson Township.

MAUCH CHUNK FORMATION.

At a point about a mile and a half south of Gurnee, on the road to Manhattan, there are exposures indicating an aggregate thickness of perhaps 60 feet or less of red clay, lying immediately below the Sharon conglomerate, which here forms the base of the Pottsville formation. This clay, which occasionally contains small fragments of red and green shale, is without doubt to be regarded as resulting from the decomposition of beds of shale of these colors. Its occurrence in the proper position of the Mauch Chunk shales points rather strongly to the probability of its belonging to this formation.

On the other hand, it is known that red beds occur at intervals throughout the vertical extent of the Catskill and Pocono formations up to 150 to 200 feet of the basal member of the Pottsville, an interval which is less than that existing between the individual red beds at many points in the Catskill-Pocono series. This occurrence of red beds at short intervals from the Chemung practically up to the Pottsville may possibly indicate that all of the rocks of this interval are to be referred to a single continuous series, but there is no evidence as to whether this continuous series is to be regarded as Catskill throughout or as representing the Pocono and Mauch Chunk as well. The beginning of the deposition of the Mauch Chunk was marked by a return to conditions favorable to the deposition of red shale. As in the case of the Catskill, the sediments were thickest in the east, and decreased gradually from a maximum of some 3,000 feet in the region of the anthracite coal field of Pennsylvania to almost nothing in the western portion of the State. To the east the sediments were evidently deposited not far from shore, and though prevailingly of red and green shale, also include considerable thicknesses of greenish sandstone. To the west the series is less sandy and the shales become distinctly calcareous and include thin beds of impure limestone, apparently indicating the existence of deeper water conditions.

Besides the point south of Gurnee, at which the red shales have been mentioned as occurring at the base of the Pottsville, they have been recognized in this position at only one other place in the vicinity of the oil field, namely, near the crest of the highlands northeast of the railroad between Galeton and West Pike. The thickness in neither case could be over 60 or 80 feet. At other points the base of the Pottsville apparently rests directly upon sandstones of Pocono type, in one place at least, the two being well exposed within a vertical interval of 15 feet of each other.

POTTSVILLE FORMATION.

Following the deposition of the Mauch Chunk shales, it seems probable that there was a moderate uplift which brought the sediments, in the western portion of their extent at least, above the level of the sea, where they were more or less eroded by streams. How much of the material was thus removed is unknown, but the amount was doubtless considerable. The erosion was probably sufficient in the western and thinner portions of the series to entirely remove the Mauch Chunk sediments, except for occasional patches, over considerable areas. The two occurrences in the Gaines region are probably patches of this nature.

While this erosion was going on in the west there was a subsidence nearer shore to the east, and the lowest of the Pottsville beds were laid down. It was considerably later when the subsidence which once more carried the eroded Mauch Chunk beds below the level of the sea began in the western portion of the State. The deposition of the Sharon conglomerate, which in the Gaines region is the lowest of the Pottsville beds, in all probability did not begin until after many hundred feet of Pottsville sediments had been laid down in eastern Pennsylvania.

The Pottsville is the uppermost of the formations exposed in the region of the Gaines oil field. It may be separated into two main subdivisions, the lower consisting of the Sharon conglomerate and the upper consisting of a series of sandstones and shales, with one or more coal seams, which overlies the conglomerate and which is identifiable by its fossils as Pottsville in age.

The Sharon conglomerate, which varies from 60 to 100 feet in thickness, is composed almost entirely of quartz, and is usually a coarse sandstone rather than a conglomerate. Notwithstanding its general sandy character, its probable identity with the Sharon conglomerate on the west makes the retention of the term desirable. The character of the sand grains and of the pebbles, both of which are usually of pure white quartz, ordinarily gives to the rock a bright, almost white, appearance, quite different from other rocks with which it is associated. Though sometimes rather thin bedded, it is more commonly massive in character, and gives rise to somewhat conspicuous cliff-like outcrops. This cliff-forming character, nevertheless, is not nearly so prominent in the vicinity of Gaines as at many other points in the State, and is apparently confined to certain of the more massive layers which, however, do not necessarily occur at exactly the same horizons in different localities.

The bed of conglomerate, though extremely resistant to the action of weathering and erosion, is nevertheless much broken in places. This is probably due in a large measure to the weathering out and removal of the softer and more easily eroded beds underlying the conglomerate, which is thus left unsupported. Large bowlders, and even flat masses of great size, are frequently broken off and slide downward, burying the slopes with great accumulations of débris.

The conglomerate occurs on each of the hills along the line of the syncline passing just north of Gaines (Pl. XLIII), beginning near Middlebury Center and continuing throughout its southwestward course across Tioga and Potter counties.

The upper, more sandy and shaly division of the Pottsville, though less widely distributed than the Sharon conglomerate, occurs nevertheless at many points along the synclines of the Allegheny Plateau. In the vicinity of the Gaines oil field it is exposed on the hill near Gurnee and on the ridge between Long and Phœnix runs. Near Gurnee nearly 200 feet of strata occur above the conglomerate. Because of their soft nature, the members are nowhere well exposed, but the following section, based largely on superficial indications, will give a good general idea of the character and succession of the individual beds. The highest formation is given at the top.

Approximate section of the portion of the Pottsville formation occurring above the Sharon conglomerate near Gurnee, Pa.

	Feet.
Buff laminated sandstone	25
Black shale	5
Coal (1.5 to 4 feet)	3
Fire clay	2
Gray and ferruginous laminated sandstone	10
Black shale	15
Fire clay	5
Buff and shaly sandstone	30
Black shale	15
Fire clay with coal streak	5
Greenish and gray argillaceous sandstone weathering yellow	60
Black shale with 3 inches of coal	5
Greenish shaly sandstone	15
Total	195

The coal varies from about 1½ to 4 feet in thickness, is soft and friable, and is rather high in sulphur. A railway was at one time built to the top of the hill, and the coal was actively worked, but it was long since practically exhausted, though a few men still find employment in getting out coal for local use. The fossil plants associated with the coal indicate, according to identifications by David White, that it is to be correlated with the Mercer group of the Pottsville. The 25-foot bed of shaly sandstone over the coal and its shale has as yet yielded no fossils, but it is almost certainly a part of the Pottsville, though there is a slight possibility of its belonging to the succeeding Allegheny series.

PLEISTOCENE DEPOSITS.

In addition to the formations described, there are somewhat abundant deposits of unconsolidated material due directly or indirectly to the presence of the ice sheet which covered the larger portion of the northern half of North America in Pleistocene times. Of these deposits, the gravel deltas formed by the streams issuing from the ice sheet have been mentioned in the description of the topography (p. 581). The most abundant and most widely distributed of the Pleistocene materials, however, is the heterogeneous mass of bowlders, sand, and clay known as till. The material is mainly of local rocks, and was derived by the pushing, rending, and dragging action of the ice upon the rocks over which it moved. Nearly the whole surface of the Gaines region outside the terraces and flood plains is covered with a deposit of greater or less thickness of such material. On the sides and crests of the hills the thickness is ordinarily rather slight, but along many of the smaller valleys and banked against certain of the slopes of the hills it may reach a thickness of 50 to 100 feet or more. In the oil wells the drive pipe is usually extended to the bottom of this unconsolidated material, and its length, therefore, serves as a measure for the thickness of the till.

GEOLOGIC STRUCTURE.

It has been seen that in the portion of the Appalachian province lying to the north and northwest of the Allegheny Front in northern Pennsylvania the folds are broad, open, and comparatively low, and are often of considerable length, though somewhat less persistent than in the more strongly folded regions.

The dips of the beds affected by the folding in the region of the Gaines oil field are usually almost imperceptible to the eye in ordinary small exposures. In the larger exposures the rocks are commonly

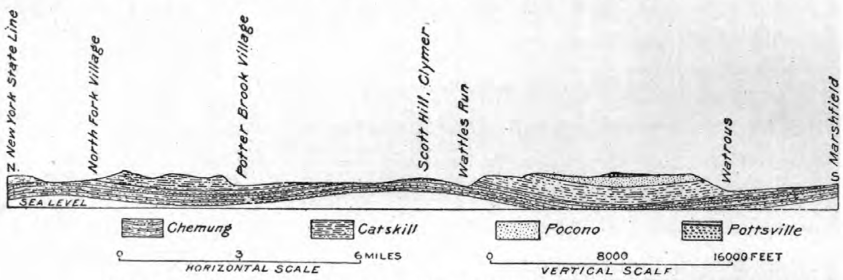
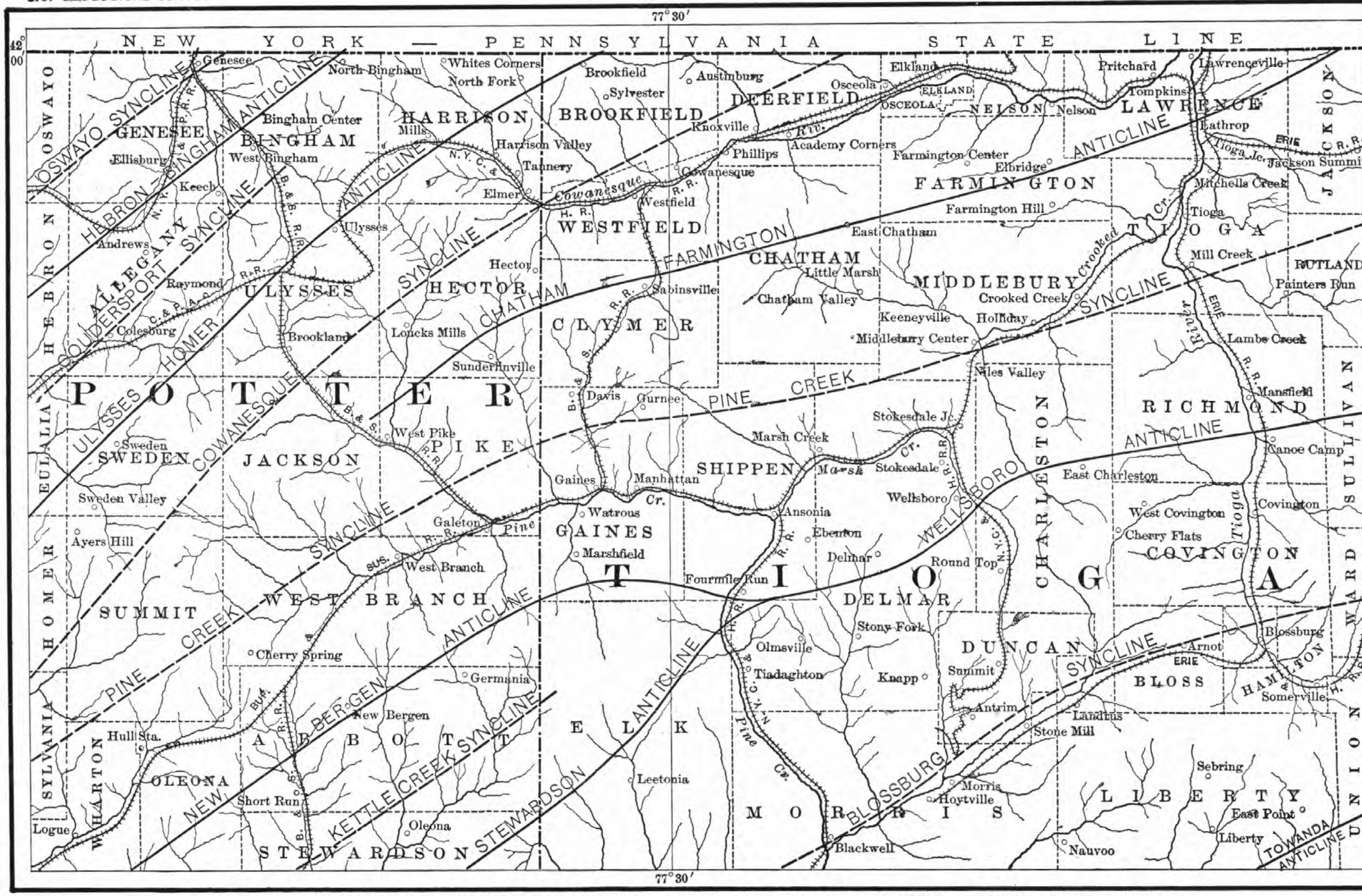


FIG. 58.—Geologic cross section from Marshfield to the New York State line.

seen to slope gently at angles of from 2° to 4°, but in some instances dips as high as 9° or 10° occur. The average dips, slight as they are, are sufficient to make a difference of some 2,000 feet between the altitude of a bed at the crest of an anticline and its altitude at the bottom of an adjacent syncline.

On Pl. XLIII are given the locations of the axes of the anticlines and synclines in the portions of Tioga and Potter counties lying within a distance of 20 to 35 miles of the Gaines oil field. In this area, which measures about 57 miles in an east-west direction and 32 miles in a north-south direction, there are six anticlinal and six synclinal axes.

Not all of the axes, however, are continuous throughout this area. The Wellsboro anticline, which is a single arch in Tioga County, becomes flattened and finally, near the Potter County line, separates into two anticlines, the New Bergen and Stewardson, separated by the Kettle Creek syncline. In a similar manner, the Chatham-Farmington anticline, which in Tioga County is represented by a strong arch, becomes flattened and almost disappears in eastern Potter County, the Cowanesque and Pine Creek synclines becoming practically united



MAP OF REGION ADJACENT TO THE GAINES OIL FIELD, PENNSYLVANIA
SHOWING THE APPROXIMATE LOCATION OF ANTICLINAL AND SYNCLINAL AXES.

Scale

6 0 6 12 MILES

into one broad basin. Again, the Hebron-Bingham and the Ulysses-Homer anticlines become united near the New York State line, the intervening Coudersport syncline having disappeared. The breadth of the folds, measured from crest to crest or from trough to trough, varies from a little over 5 to nearly 20 miles.

The section given in fig. 58 shows the geologic structure along a line extending nearly due north from Marshfield to the New York State line. The axis of the Pine Creek syncline is located a few miles north of Watrous, that of the Cowanesque syncline near Potter Brook, while the axes of the Chatham-Farmington and Ulysses-Homer anticlines are near Scott Hill and North Fork Village, respectively. The crest of the New Bergen anticline is not shown in the section, but it is probably located about a mile south of Marshfield. On this supposition the center of the Gaines oil field at Watrous is about halfway between the crest of this anticline and the bottom of the Pine Creek syncline to the north.

LOCAL STRUCTURE.

The location of the oil field is near a point at which both the anticline and the syncline swing to the south. Starting at a point about a mile south of the town of Wellsboro, the anticlinal axis bears S. 60° W. for a distance of some 5 miles, then gradually turns, bearing first due west, then N. 85° W. to a point about a mile south of Marshfield and 3 miles south of Watrous. Here again it makes a sharp bend, changing through an arc of about 35° to a course S. 60° W., which it retains for a distance of many miles. In the vicinity of Wellsboro the anticline is well developed, but becomes gradually lower and more flat to the southwestward, and finally, at a point about 5 miles south of Ansonia, divides into two distinct anticlines. The northern member pursues the course described above, while the southern member takes a course nearly S. 45° W. for 10 miles or more before swinging into parallelism with the northern member.

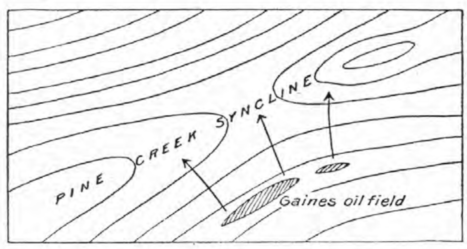


FIG. 59.—Contour sketch of the structure in the vicinity of the Gaines oil field, showing the divergence downward and convergence upward of the rock inclinations.

The Pine Creek syncline, starting from Middlebury Center, about 6 miles north of Wellsboro, bears S. 80° W. to the vicinity of Gurnee, where it bends through an arc of about 20° to a course S. 60° W., parallel with that of the Wellsboro anticline. The deepest portion of the syncline is near Gurnee, north of Manhattan. North of Gaines and Watrous it is some 200 feet shallower, but again deepens west of Galeton and Cushing Creek (fig. 59).

Where such bends occur in the direction of the axis of a fold the rocks upon the inside of the turn necessarily possess more or less convergent upward or divergent downward inclinations. This upward convergence apparently furnishes conditions particularly favorable to the gathering of oil into a pool, and has possibly been an important factor in the Gaines field. Fig. 59 illustrates graphically, by means of arbitrary contours, the downward divergence, or upward convergence, of the rock inclinations in the vicinity of the oil field.

From the depths of the producing sand, as reported by the drillers, and the location and elevation of the wells, as determined by the writer, the contour map of the upper surface of the Atwell sand represented in fig. 60 has been constructed. It will be noted that the difference between the elevation of the sand, which is given in feet above sea level, at the northern and southern limits of the pool, as

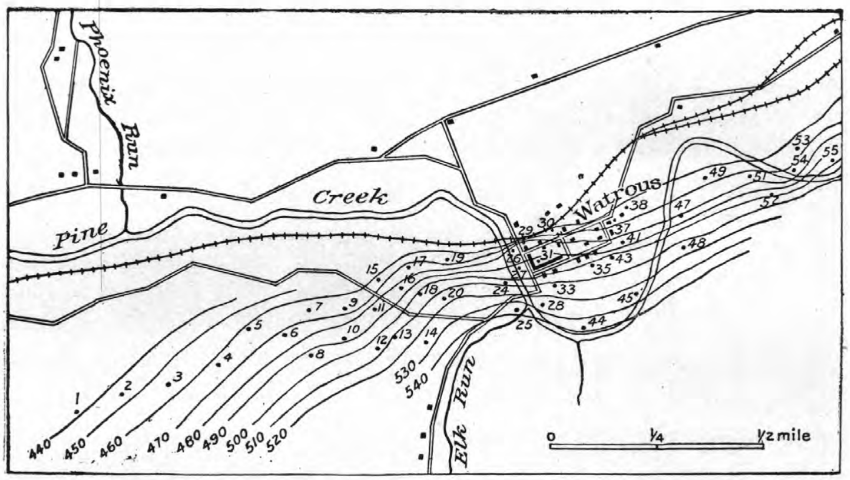


FIG. 60.—Contour map of the upper surface of the Atwell sand.

indicated by wells No. 44 (Dimmick 7) and No. 30 (Legal 1), is some 80 feet, pointing to a dip of about 6 feet in 100. The dip is not uniform throughout the field, as will be seen from the contours, but is steepest in the central and eastern portions and most gentle near the western limits. Another noticeable feature is the considerable bend to the south made by the contours west of Watrous, indicating a marked change in the line of strike of the rocks. This bend is borne out by observed strikes along Elk Run, and in amount is probably underestimated rather than overestimated.

The most important fact brought out by the contours, however, is the nonparallelism of the productive belt with the direction of strike in the western portion of the pool. In the eastern and central portions the wells clearly agree with the strike, but about half a mile west of Watrous the wells no longer follow this line, but encounter the sand and obtain their oil supplies at progressively lower horizons as the distance to the west increases.

Wells drilled to the south of the present line of wells and nearer in line with the strike are reported to have found the Atwell sand in greatly diminished thickness and nearly barren of oil. This thinning out of the producing sand is probably the cause of its supposed failure when followed along the strike west of Watrous. Whether a sufficient number of wells have been drilled to completely demonstrate the absence of oil along this line of strike is perhaps doubtful.

In the producing portion of the Atwell sand the dips, as indicated by the contours, are rather gentle, there being a fall of only about 6 feet in 100, or a dip of some 3½°. If the exposures along Pine Creek just north of the Atwell and Knoxville groups of wells (Pl. XXXIX, wells 53 to 62) are to be taken as criteria, however, the dips immediately to the north of the producing field are much steeper, dips as high as 8° or 10° having been observed. If the same structure holds at the depth of the Atwell sand it furnishes a probable explanation for the accumulation of oil at the point at which it is found, as the flattening of the dip would furnish an obstruction that would for the time prevent any further upward progress of the oil and would cause it to accumulate along the flatter portion of the bed. The conditions are represented diagrammatically in fig. 61, in which the bed A A′ represents the Atwell sand and in which the change from steep to gentle dips is at *a*. The oil is found immediately above (south of) this change of dip.

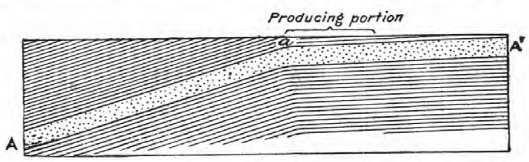


FIG. 61.—Section showing change of dip at northern edge of the producing portion of the Atwell sand in the Watrous oil pool.

In the western portion of the field the thinning of the sandstone as exhibited in the more southerly of the wells furnishes an additional cause for the arrest of the oil. Near Watrous oil was encountered in the Dimmick No. 9 (Pl. XXXIX, well 38) at an altitude above sea level of 524 feet, but in the western portion of the field it has been unable, because of the presumable thinning out of the sandstone, to rise to an altitude of more than 440 feet.

HORIZON OF THE ATWELL SAND.

The depth of the top of the Atwell sand below the base of the Catskill is about 700 feet, so that it is among the lower of the horizons from which oil has been obtained in Pennsylvania.

The sands which produce the oil of Venango and Butler counties belong to the Catskill formation, which in the Gaines region is usually absent through erosion from the crests of the anticlines and is not usually very deeply buried even in the synclines. It is not likely, therefore, that it will ever become a prominent source of oil in the latter region. Small shows of a heavy lubricating oil have been reported, however, as occurring in some of the sandy members of the formation in certain of the wells sunk to the "Blossburg formation."

The Big Injun sand of the upper portion of the Pocono, which has produced oil in some quantities in southwestern Pennsylvania, is absent over most of the region about Gaines. When it occurs it is only in the upper portion of the higher ridges lying along the synclines.

The Mahoning sandstone, which has also produced oil in southwestern Pennsylvania and in West Virginia, is not represented in northern Pennsylvania, having been long ago removed by erosion.

SUMMARY OF SIGNIFICANT STRUCTURAL FEATURES.

1. The producing portion of the Atwell sand lies about midway between the top of an anticline and the bottom of the adjoining syncline. Below it, and between it and the bottom of the syncline, lies a belt of salt water, as determined by "wild-cat" wells, while immediately above it is a zone which in several instances has furnished gas in considerable amounts.

2. The oil occurs several hundred feet below the limit to which the surface waters have penetrated the rock. In general, it may be said that it is useless to expect oil to occur in paying quantities above this level, for it is evident that where surface water can penetrate downward it is equally possible for oil to escape upward and become lost from the rock.

3. The oil field occurs opposite a somewhat marked southward bend of both the anticline and the syncline, a position which the more or less convergent upward inclination of the rocks makes particularly favorable to the gathering together of the oil. (See Pl. XLIII and fig. 59).

4. The field is situated opposite a shallow portion of the syncline between two basins (fig. 59, p. 617), and opposite a somewhat flat portion of the anticline. Both of these factors tend to give the oil field dips which are somewhat flatter than those ordinarily prevailing. Such flat dips are favorable to the retention of the oil in the rock.

5. There is apparently a further local flattening of the dip in the immediate vicinity of the producing belt (fig. 61, p. 619), which still further favored the accumulation of oil.

6. The producing belt, in its western portion, is not parallel with the strike of the rocks, but lies considerably north of it, and at a level which becomes progressively lower westward of Watrous. At the same time the more southerly wells show that the sand is decreasing

in thickness in that direction, furnishing by its thinning out an explanation of the probable absence of oil south of the present developed belt

7. While not found at the top of the anticline, the position of the oil in the Gaines field is in general agreement with the anticlinal theory of the occurrence of oil. The convergent upward inclination of the rocks at the bend of the folds gives a cause for the gathering of the oil, while the flattening of the dips furnishes a reason for its retention in a pool. At the crest of the anticlines the Atwell sand is either entirely removed by erosion or lies sufficiently near the surface to become permeated by surface waters, to the exclusion of any oil it may have contained.

FUTURE PROSPECTS OF THE REGION.

LIMITATIONS OF THE PRESENT FIELD.

The outlines of both of the pools of the Gaines oil field appear to be rather definitely fixed by the surrounding dry wells and by the character of the wells along the border of the producing belt itself. On the northern or lower edge of the producing zone the wells generally show evidences of salt water, the presence of which is accepted by the operators as indicating close proximity to the limits of the productive area. The same is true in regard to the occurrence of wells low in oil but high in gas along the southern or upper edge of the producing zone. While not furnishing an absolute criterion for the fixing of the limits of the field, it is probable that the limits so fixed are very nearly correct.

The fact, previously noted, that the line of wells to the west of the easternmost of the Scott & Fay wells does not follow the southward bend in the strike of the rocks, as would naturally be expected, but lies along a direct continuation of the axis of more easterly portions of the field, raises the question as to whether the prospecting has been sufficient near the bend in the strike to show that the oil does not in reality occur in its normal position along this line. The evidence of the Scott & Fay wells 5, 7, and 9 (14, 12, and (?) on map) of the W. H. Watrous lot and of the wells of the C. H. Watrous lot (1–5 on map), all of which are low in oil, seems to indicate a close proximity to the margin of the producing area. The only doubtful point is along the strike of the rocks (approximately S. 50° W.) southwest of wells 4 and 8 (10 and 8 on map) of the W. H. Watrous lot. The geological position along this line is somewhat favorable to the occurrence of oil, but its presence there is made doubtful by the rapid thinning of the sandstone in that direction as recorded by the more southerly of the wells. The outlook, therefore, for paying wells at this point is not good.

New wells are still being sunk in the Gaines field within the limits of the producing belt as already defined, but are meeting with small success, and though it is possible that a few more producing wells might be obtained within or along the borders of the field, it is not likely that oil will be obtained in paying quantities. Neither does it seem likely that any of the rocks occurring at a moderate depth beneath the Atwell sand or "Blossburg formation" will produce oil in paying quantities, for a number of wells have been drilled to depths of from 1,200 to 1,800 feet or more without encountering further oil.

PROSPECTING IN ADJACENT REGIONS.

Besides the wells sunk in the immediate vicinity of the Gaines field, wells have been sunk in most of the surrounding townships in Tioga and Potter counties. Oil shows, and sometimes very slight amounts of oil, have been encountered in a number of these wells, but no productive wells have been developed. Gas has been found in considerable amounts and under heavy pressure in some of the wells and has been piped for local use.

The scattering wells do not bear any fixed relationship to the geologic structure, but vary in their positions from the tops of anticlines to the bottoms of synclines.

While the prospecting or sinking of "wild-cat" wells has been carried on to an extent which makes it unlikely that an oil pool of any considerable size will be discovered in the future, it is probably safe to say that the testing has not been so thorough but that an oil pool of the size of the Gaines field may have escaped discovery.

In the selection of sites for the drilling of "wild-cat" wells in the region adjacent to the Gaines oil field it is well to bear in mind that all of the wells of this field start in the Catskill formation at horizons from 150 to 250 feet or more above its base. In the very regular folds of the surrounding region the outcrop of the Catskill, characterized by frequent beds of red or reddish shales and sandstones, usually possesses the same general relation to the folds as a whole that it has at Gaines, and may therefore be used as a rough guide in the determination of the location of points of similar geologic position and structure.

Though the outlook for new pools can not be said to be encouraging, it is probable that new wells will continue to be sunk. In order to furnish an accurate base for the determination of the altitude of such wells, and for the calculation of the geologic structure and position of recognized beds, a list of bench marks established by the Geological Survey in the region north and northeast of Gaines as far as the New York State line is here appended. The principal structural features of the region have been considered under "Geologic structure," pp. 616–621.

LIST OF PERMANENT AND TEMPORARY BENCH MARKS IN TIOGA AND POTTER COUNTIES, PENNSYLVANIA.[a]

The following elevations are based on an aluminum tablet placed in the State Library at Harrisburg, the elevation of which is accepted as 363.813 feet above mean sea level.

The leveling was done under the general direction of Mr. J. H. Jennings, topographer, by Messrs. C. H. Semper and Robert Coe, levelmen.

All bench marks dependent on this datum are marked with the letters "HARRISBURG," in addition to their figures of elevation.

ELKLAND.

	Feet.
Elkland; top of spike in timber culvert on west side of railroad, 100 feet north of tannery switch, chisel marked "U.S.G.S., B.M. 1146"	1,145.53
Elkland; tablet set in front face of Pattison Bank, on West Main street, marked "1134 HARRISBURG 1899"	1,133.632

ELKLAND TO LAWRENCEVILLE.

Nelson; top of coping stone of culvert, 200 feet west of station, south side of railroad, chisel marked "U.S.G.S., B.M. 1171"	1,170.96
Nelson; tablet set in southeast corner of Nelson schoolhouse, marked "1077 HARRISBURG 1899"	1,077.178
Nelson, 1 mile east of; on top stone at north end east abutment of small bridge, 350 feet east of milepost 80–33	1,120.75
Pritchard; railroad spike in second telegraph pole west of section house	1,013.11
Lawrenceville, 1½ miles west of; on top of stone at north end of east abutment of New York Central and Hudson River Railroad bridge over Cowanesque River	1,011.49
Lawrenceville; aluminum tablet in top foundation stone on south side near southeast corner of building at northwest corner of Main and Cowanesque streets, owned by estate of J. F. Rushling and occupied by Wing & Bostwick as a general store, marked "996 HARRISBURG 1899"	995.992

ELKLAND TO ACADEMY CORNERS.

Osceola; top of bolt in guard rail on wooden bridge 600 feet west of station, north side, west end of bridge, chisel marked "U.S.G.S. B.M. 1155"	1,155.47
Osceola, 1.9 miles west of; top of bolt in guard rail of culvert, on south side, chisel marked "U.S.G.S. B.M. 1177"	1,177.35
Academy Corners; tablet set in southeast corner of district schoolhouse, marked "1216 HARRISBURG 1899"	1,215.925

ACADEMY CORNERS, VIA LITTLE MARSH AND KEENEYVILLE, TO MIDDLEBURY.

Academy Corners, 6 miles south of; on rock on south side of road culvert, in culvert wall, 100 feet west of forks in road, junction of Close and Bates Hill roads, ½ mile north of Little Marsh, chisel marked "U.S.G.S. B.M. 1590"	1,590.41
Little Marsh, at east end of village of; copper tablet in top of third stone from east end of north abutment of iron highway bridge over Crooked Creek, marked "1392 HARRISBURG 1899"	1,392.384

[a] Reprinted from report on Triangulation, primary traverse, and spirit leveling: Twenty-first Ann. Rept. U. S. Geol. Survey, Part I, pp. 431–435.

	Feet.
Little Marsh, 1 mile east of; on point of a bowlder on left side, 70 feet east of a small bridge	1,384.87
Chatham Valley, ½ mile east of; on rock on left of road, at north end of small culvert	1,314.06
Keeneyville, 1½ miles west of; on flat bowlder 10 feet to right of road, near barn of Mrs. Fanny Goodwin	1,276.41
Keeneyville, ½ mile west of; on maple, 12 inches diameter, on right of road, opposite cemetery	1,277.12
Middlebury; copper tablet in top stone at south end of west pier of iron highway bridge over Crooked Creek, marked "1149 HARRISBURG 1899"	1,149.204

ACADEMY CORNERS TO WESTFIELD.

Knoxville; aluminum tablet set in about the middle of foundation of chimney on west side of residence of H. I. Brewster, on south side of East Main street, being the third building from corner of Main and Water streets, marked "1239 HARRISBURG 1899"	1,239.568
Knoxville; railroad spike in root of maple, 18 inches diameter, at northwest corner of New York Central and Hudson River Railroad station	1,232.57
Knoxville, 1½ miles west of; railroad spike in root of elm, 15 inches diameter, 40 feet south of track, about 2,100 feet east of milepost 49–19	1,261.94
Cowanesque, ¼ mile east of; railroad spike in nearest telegraph pole to milepost K 70 (Buffalo and Susquehanna Railroad)	1,296.62
Westfield, 1 mile east of; on inside anchor bolt on north side east abutment of Buffalo and Susquehanna Railroad bridge over Cowanesque River	1,330.49

	Feet.
Westfield; aluminum tablet in east face of top foundation stone at the northeast corner of brick building at corner of Main and Church streets, owned by F. D. Strang, marked "1372 HARRISBURG 1899"	1,371.710

WESTFIELD TO BINGHAM.

Westfield, 1 mile west of; on top of stone at south end of ballast wall on west abutment of bridge 450 feet east of milepost 99–14	1,383.77
Potter Brook, 1 mile east of; on point of bowlder 10 feet to right of track	1,439.92
Potter Brook; on east side of south end of water-tank foundation	1,463.64
Potter Brook, 1 mile west of; railroad spike in nearest telegraph pole to milepost 102–11	1,497.85
Elmer, 1 mile west of; on top of stone at south end of east abutment of bridge 100 feet west of milepost 103–10	1,546.22
Harrison Valley; copper tablet set in south face of top foundation stone at the southeast corner of brick building owned by G. E. and D. T. Stone, marked "1618 HARRISBURG 1899"	1,618.463
Harrison Valley, 1 mile west of; railroad spike in top of corner pile at east abutment of bridge, 1,150 feet west of milepost 105–8	1,660.69
Mills; railroad spike in root of cherry tree 18 inches diameter, 40 feet south of track near dancing pavilion at I. O. O. F. Park	1,721.28
Mills, 2½ miles west of; copper tablet in top of corner coping stone on north side of east abutment of bridge about 1,100 feet east of milepost 109–4, marked "2022 HARRISBURG 1899"	2,022.077
Bingham, ¾ mile east of; on silver poplar, 15 inches diameter, 30 feet south of track and 280 feet east of east end of logging switch	2,079.04

WESTFIELD TO GAINES, SUNDERLINVILLE, GALETON, AND WEST PIKE.

	Feet.
Westfield, 1½ miles south of; on elm, 20 inches in diameter, 25 feet to right of track, 600 feet north of milepost K 66	1,457.15
Sabinsville, at north end of village of; copper tablet in top of corner stone on north side east abutment of iron highway bridge over Mill Creek, marked "1601 HARRISBURG 1899"	1,601.409
Sabinsville, 1 mile south of; on bowlder on right of track in cut	1,553.57
Sabinsville, 2 miles south of; railroad spike in birch, 18 inches diameter; 40 feet left of track, near south end of Summit siding	1,727.99
Lansing, 1 mile north of; on bowlder on right of track, 480 feet north of milepost K 60	1,612.01
Lansing (railroad station is Davis); railroad spike in first telegraph pole at north end of railroad station	1,530.61
Lansing, 1 mile south of; on outside spike of switch stand at Gurnee switch	1,482.15
Gaines, 3 miles north of; on bowlder on right of track, 780 feet north of milepost K 57	1,442.11
Gaines; copper tablet in south face of foundation stone at the southeast corner of Hotel Vermilyea, marked "1294 HARRISBURG 1899"	1,294.145
Gaines, 1 mile west of; on top of ballast wall on south side of east abutment of steel railroad bridge over Pine Creek	1,262.32
Galeton, 2 miles east of; on bowlder 6 feet to left of track, 110 feet west of milepost K 51	1,291.05
Galeton; on top of stone at east end of south pier of highway bridge over Pine Creek, south of tannery	1,321.515
Galeton; aluminum tablet in window sill on east end near southeast corner of building used as general offices of Buffalo and Susquehanna Railroad, marked "1330 HARRISBURG 1899"	1,329.978
Sunderlinville, 5 miles south of; on bowlder on left of road near small bridge near forks of road near sawmill	1,412.57
Sunderlinville, 3 miles south of; on top of stone on north side of west abutment of iron highway bridge over Phœnix Creek	1,497.91
Sunderlinville, 1 mile south of; on elm, 36 inches diameter, 15 feet to left of road, near top of hill	1,693.72
Sunderlinville; aluminum tablet in west face of foundation stone near northwest corner of building used as hotel, owned by E. S. Worden, at the southwest corner of the forks of road, marked "1738 HARRISBURG 1899"	1,738.203
Galeton, 1¾ miles northwest of; on top of ballast wall on east side of north abutment of steel bridge	1,364.68
West Pike, 1 mile southeast of; railroad spike in root of hemlock 70 feet to left of track and 250 feet south of highway crossing	1,437.77
West Pike; a square hole in top of stone at north end of west abutment of steel railroad bridge over Genesee Fork of Pine Creek	1,461.17

GAINES TO STOKESDALE AND WELLSBORO.

Gaines, 1 mile east of; on top of stone at north end of west abutment of iron bridge	1,221.17
Manhattan; on top of stone at south end of west abutment of bridge 150 feet east of railroad station	1,208.75
Ansonia, 3 miles west of; on top of stone at south end of west abutment of iron bridge	1,176.15

	Feet.
Ansonia, 1 mile west of; on top of stone at south end of east abutment of small bridge	1, 142. 67
Ansonia; copper tablet in top of bridge-seat stone on north side of east abutment of highway bridge over Marsh Creek 200 feet west of Fall Brook Railway, marked "1136 HARRISBURG 1899"	1, 136. 084
Ansonia, 1 mile northeast of; railroad spike in milepost 100–71	1, 143. 39
Marsh Creek, ½ mile west of; on top stone at north end of west abutment of small bridge 500 feet east of milepost 72–99	1, 152. 19
Marsh Creek, 1½ miles northeast of; railroad spike in milepost 74–97	1, 169. 89
Stokesdale Junction, 3 miles southwest of; on bowlder 5 feet to right of track and 70 feet south of milepost 75–96	1, 160. 69
Stokesdale Junction, 2 miles southwest of; on foundation of water tank near milepost 76–95	1, 158. 73
Stokesdale Junction, 1 mile southwest of; on top of stone at west end of north abutment of small bridge 400 feet south of milepost 77–94	1, 164. 59
Stokesdale; on inside anchor bolt on west side at south end of through truss railroad bridge	1, 189. 76
Wellsboro, 1 mile north of; on top of stone at west end of south abutment of bridge near milepost 15–95	1, 242. 50
Wellsboro; copper tablets in stone monuments set in public square as meridian marks. The north monument is about 7 feet from Central avenue and 42 feet from Main street. The south monument is about 13 feet from Pearl street and 26 feet from Charles street, marked "1308 HARRISBURG 1899."	
North monument	1, 307. 838
South monument	1, 308. 505

STOKESDALE TO MIDDLEBURY.

Stokesdale Junction; on west end of south abutment of small bridge at north end of coal shutes	1, 163. 64
Stokesdale Junction, 1 mile north of; on top of milepost 79–92	1, 174. 27
Middlebury, 2 miles south of; railroad spike in milepost 80–91	1, 174. 09
Middlebury, 1 mile south of; on outside rivet of east side at south end of plate girder railroad bridge	1, 162. 88

SUMMARY OF FUTURE PROSPECTS.

The conclusions in regard to the future of the Gaines oil field and the surrounding region may be summarized as follows:

(1) The wells of the Atwell sand will probably continue to produce oil in limited amounts for some time to come.

(2) Small flows might possibly be obtained by a limited number of new wells in the developed area of the Atwell sand, though probably at the expense of the older wells.

(3) It is not entirely impossible that further "gushers" may be encountered in the Blossburg formation, but the pool has been pretty thoroughly covered by wells and the chances for new wells are very slight.

(4) The chances for obtaining flows from sands below the Atwell sand and the "Blossburg formation" and within a moderate distance from the surface do not seem to be good, judging from the failure of the deeper wells.

(5) The probability of any material extension of the present field is extremely slight, though it is not impossible that a few more very small wells might be obtained along the borders of the belt. The geological conditions are apparently more favorable for obtaining a further supply at points along the strike of the rocks (approximately S. 50° W.) southwest of the Scott & Fay wells 4 and 8 on the W. H. Watrous lot than elsewhere along the borders of the field. It is extremely doubtful, however, if the oil would occur in paying quantities.

(6) Oil sands have been found in other States at horizons lower than any yet reached by wells in the Gaines field, and it is not impossible that oil may occur at great depths. The chances of finding it in quantities sufficient to compensate for deep drilling are not good, though nothing but drilling can decide this question.

(7) There are points in the region surrounding the Gaines field in which the general geologic structure appears to be as favorable to the occurrence of oil as at Gaines itself, but whether or not the necessary local conditions, such as flattening of dip, etc., are also present can not be told without minute study of the whole region. It is possible that there may still be undiscovered pools of small size in the surrounding region, but such pools would be extremely difficult to locate because of their limited extent.

(8) Sufficient drilling has been done in the region about Gaines to indicate the improbability of the existence of any large pool of oil.

THE PORTLAND CEMENT INDUSTRY IN MICHIGAN

BY

ISRAEL C. RUSSELL

CONTENTS.

ILLUSTRATIONS.

THE PORTLAND CEMENT INDUSTRY IN MICHIGAN.

By Israel C. Russell.

HISTORICAL SKETCH.

The history of the Portland cement industry in Michigan begins with the year 1872, when the Eagle Portland Cement Company, with headquarters at Chicago, built a cement plant about 2 miles northeast of Kalamazoo.[a] This plant was constructed by Bush & Patterson, of Kalamazoo, who subsequently became its owners. At first it consisted of two kilns, the number being afterwards increased to four. The kilns were circular in ground plan, about 16 feet in diameter, and of the general character of the bee-hive ovens used in burning charcoal. The materials used were marl and surface clay dug from deposits near the kilns, which after mixing were air dried and then cut into rude bricks, which were more thoroughly dried over furnaces in which wood was used for fuel. The bricks were then put in the kilns together with alternating layers of coke and calcined by the heat of the burning coke. The clinker produced was ground by means of millstones. The product of the plant, known as "Eagle Portland cement," is reported to have been about 100 barrels a day, and was sold at wholesale at from $4 to $4.25 a barrel. The factory was continued in operation until about 1882, but no traces of the kilns are now in existence. Some 3 miles of sidewalk were put down in Kalamazoo with this cement, and after fifteen or twenty years are still in excellent condition.

The next factory for making Portland cement was erected by the Peerless Portland Cement Company, in 1896 and 1897, at Union City. In this plant vertical or dome kilns were used, as will be described later. This was the beginning of the recent great development of the Portland cement industry in Michigan, and was followed by the erection of the factories of the Bronson Portland Cement Company at Bronson, in 1897, and of the Michigan Portland Cement Company at Coldwater, in 1898, in both of which factories the modern rotary kilns

[a] An attempt to obtain hydraulic cement by calcining impure limestone, wood being used for fuel, was made at Trowbridge dam, on Thunder Bay River, 7 miles northwest of Alpena, in 1866, but was not successful, owing apparently to the poor quality of the material used. So far as known, this is the only effort on a commercial scale to manufacture what is known as "natural cement" in Michigan. Natural cement, as is well known, is obtained by calcining a natural mixture of calcium carbonate, alumina, and silica, that is, an argillaceous limestone, which approaches in composition more or less closely the artificial mixture employed in making Portland cement.

are used. The rapid development of the industry which followed the successful operation of the factories at Union City, Bronson, and Coldwater, is indicated by the data assembled in the table on pages 684–685.

CHARACTERISTICS OF PORTLAND CEMENT.

COMPOSITION.

For the benefit of the general reader, as well as for the sake of furnishing suggestions to persons about to engage in the Portland cement industry, the following sketch, showing the nature of Portland cement, the materials used in making it, methods of manufacture, etc., is introduced.

Portland cement is an artificially prepared substance which has the property of hardening in air or water when mixed with a suitable proportion of water and of remaining hard when immersed in water. Its chief value lies in the fact that when used in masonry it produces a strong bond, which does not weaken when submerged in water or exposed to a damp atmosphere. In its manufacture an intimate mechanical mixture of finely pulverized limestone, or marl, and clay, or ground shale, is calcined or "burned," as the common expression is, and the resulting "clinker" ground to a fine powder, which is the Portland cement of commerce. The finished cement does not necessarily have a definite and fixed composition, as considerable variation is permissible, and excellent results may still be obtained. The degree of variation in chemical composition usually considered allowable is indicated in the first column of the following table,[a] which has been prepared from a large number of analyses of good Portland cements:

Analyses showing permissible variations in the composition of Portland cement, and in the mixture from which it is made.

Constituent.	Portland cement.	Mixture of marl and clay before burning.
	Per cent.	*Per cent.*
Silica, SiO_2	20.00 to 24.00	12.68 to 15.22
Alumina, Al_2O_3	6.00 to 10.00	3.80 to 6.34
Ferric oxide, Fe_2O_3	3.00 to 5.00	1.90 to 3.17
Calcium oxide, CaO	60.00 to 64.00	38.04 to 40.58
Magnesium oxide, MgO	1.00 to 3.50	0.65 to 2.25
Sulphuric anhydride, SO_3, before addition of gypsum	0.50 to 0.70	0.35 to 1.25

As is indicated above, the permissible variation in the finished product allows considerable latitude in selecting the raw materials, but the limestone and clay need so to supplement each other that, when

[a] For this table and also for much of the information presented in this section, the writer is indebted to Prof. E. D. Campbell, of the University of Michigan.

mixed in the proper proportion ready for burning, the chemical composition will not vary beyond the approximate limits indicated in the second column of the above table.

As a guide in selecting the raw materials for use in making Portland cement, the following table of analyses of limestone, marl, clay, and shale which are used by successful factories or have given satisfactory results in making small quantities of cement in the laboratory, is here presented:

Analyses of the raw materials used in making Portland cement.

Constituent.	Limestone.		Marl.		Clay.		Shale.	
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
Silica, SiO_2	3.53	2.14	0.52	0.20	59.15	61.68	65.25	49.93
Alumina, Al_2O_3	1.14	1.46	0.51	0.50	19.85	19.60	21.06	25.33
Ferric oxide, Fe_2O_3			0.53	0.60	8.30	3.12	3.40	6.05
Calcium oxide, CaO	54.45	52.84	51.66	50.12	3.03	2.40	0.84	3.12
Magnesium oxide, MgO	0.44	1.04	1.37	0.83	1.36	1.77	1.78	1.65
Sulphuric anhydride, SO_3	......	......	0.89	0.56	......	0.43	......	0.38
Loss on ignition	38.74	42.52	44.52	47.19	8.02	7.18	6.10	10.19
Total	98.30	100.00	100.00	100.00	99.71	96.18	98.43	96.65
Computed:								
Calcium carbonate, $CaCO_3$	97.23	94.35	92.25	89.50	......	......	......	......
Magnesium carbonate, $MgCO_3$	0.92	2.18	2.87	1.74	......	......	......	......

These analyses indicate a desirable chemical composition of limestone or marl and clay or shale for the manufacture of Portland cement. The material used should be as free as possible from sulphur and magnesia. The greatest amount of sulphuric anhydride (SO_3) that can safely be allowed in the raw material is about 1 per cent, but preferably it should be less than 0.5 per cent, while magnesium oxide (MgO) should not exceed 2 per cent. In the finished cement, before calcium sulphate is added to regulate the rate of setting, as is a common practice, the sulphuric anhydride present should not exceed approximately 0.5 per cent, and magnesium oxide under American practice should not be in excess of 3.5 per cent, although certain German authorities place the maximum at 4 per cent. It may be stated here, however, on the authority of Prof. E. D. Campbell, of the University of Michigan, that the influence of magnesia on the strength and soundness of Portland cement, although not well understood, seems from recent experiments to be under certain conditions much less injurious than is commonly supposed. Other substances which are frequently present in small quantities in the raw materials used have, in general, but little if any injurious effect, and may be considered as adulterants. A general rule in mixing the raw materials to be burned for cement is that the ferric oxide and alumina should be about one-third to one-half of the amount of silica present.[a]

The raw materials for cement should not only be of proper chemical composition; it is important that they should have certain physical properties. Chief among these is an absence of sand, for if the silica present is in the form of quartz grains or kernels it will not combine readily with the calcium oxide when calcination takes place. The silica should be combined silica, as, for example, the aluminum silicate of clay, unless it is crushed or otherwise reduced to an excessively fine powder. Both the limestone and the clay or shale should be of such consistency that they may be readily pulverized, otherwise the cost of grinding becomes an excessive item. The ideal lime ingredient is a soft, incoherent, fine marl, of uniform composition; or, if limestone is used, it is desirable that it be so soft that the expense of grinding to a suitable degree of fineness may be reduced to a minimum. Pure limestone is usually hard, and the varieties having an admixture of clayey material are preferable, as they are commonly soft and comparatively easy to work. Certain spring deposits, known as calcareous tufa and travertine, are also frequently favorable for use in this connection. The most desirable clay, providing it has the requisite chemical composition, is one which is free from sand and which when agitated in water will readily separate into fine particles. The best clays for cement making frequently have a greasy, unctuous feeling and are smooth to the touch. Hardened clay or shale, and even clay containing much sand and gravel, may be used, but it requires thorough grinding, and, on account of the expense thus involved, should not be chosen except in the absence of softer and finer material having the requisite chemical composition. It is highly desirable also that both the limestone or marl and the clay or shale be of nearly constant chemical composition throughout, in order that the difficulty of combining them in the proper proportion in a uniform mixture may be reduced to a minimum.

In addition to the raw materials which enter directly into the composition of Portland cement, fuel is necessary for burning them. For this purpose in upright kilns crushed coke is generally utilized; and in the rotating kilns, now commonly used in America, a jet of gas, petroleum, or finely pulverized coal, forced in by means of an air blast, is employed. The character of the coal desirable for this purpose will be considered later in describing the fuel used in the Portland cement plants of Michigan.

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[a] The chemistry of Portland cement, processes of manufacture, etc., have been admirably discussed in the following publications:

The constitution of hydraulic cements, by S. B. and W. B. Newberry: Jour. Soc. Chem. Industry, Vol. XVI, 1897, pp. 887–894.

Portland cement—Sketch of methods and processes, by S. B. Newberry: Eng. Rec., New York, Vol. XLII, 1900, pp. 436-438; reprinted in The Cement Industry, New York, 1900, pp. 9–19.

STYLES OF KILNS.

Two types of kilns are used in burning Portland cement. The first and older type is an upright cylinder of brick or stone lined with fire brick, about 40 feet high, 16 to 20 feet in diameter, drawn in at the top, and essentially like the continuous kilns used in burning lime. The lime and clay, after having been molded into bricks and dried, are introduced into the kiln, together with alternating layers of crushed coke, through an opening about the middle of the side. The burning of the coke calcines the bricks of lime and clay, and the resulting clinker is removed from an opening at the base of the kiln. The process is a continuous one, the raw material being added from time to time as the clinker is removed.

The second type of kiln, and the one now almost universally used in America, consists of a steel cylinder, usually 60 feet long and 6 or 7 feet in diameter, lined with refractory material. These furnaces, as they may justly be termed, are placed in a nearly horizontal position, being inclined at an angle of about 2°, and made to rotate by means of gearing attached to the outside. When "rotaries" are used, one of two methods of manufacturing cement, known as the "wet" and the "dry" process, may be employed. In the former the finely ground marl or limestone and clay is mixed with about 60 per cent of water, and this "slurry" is caused to flow into the higher end of the rotary in a small stream. In the dry process the slurry contains only sufficient water to moisten the powdered charge and prevent it from being blown away as dust. In each case a jet of fuel is forced in at the lower end of the rotary and a temperature of from 2,500° to 3,000° F. obtained. The rotation of the furnace causes the slurry to advance down the cylinder, where it is first dried, and as it travels farther the carbon dioxide is driven off, leaving the calcium oxide free to unite with the silica present, and as the charge approaches the hot end of the furnace, it is raised to a white heat. The resulting clinker runs from the rotary in a continuous stream of white-hot pellets, usually from a quarter to half an inch in diameter. It is received in a conveyor and removed to another part of the factory, where, after cooling, it is ground to a fine powder. While the general process briefly outlined above is followed in all the factories using rotaries, there is great variation in details, such as the manner in which the materials used are mixed and ground together, in the way the blast of flame is produced and controlled, in the manner of conveying the clinker, in methods of grinding the clinkers, etc. In fact, no two factories, although built in the same general way and using the same kind of raw materials and the same process, are alike, but each one has an individuality of its own.

The cement as it comes from the grinding machines is of such fineness that at least 90 to 98 per cent will pass through a sieve having 100 meshes to the linear inch. It is then ready for use, but usually improves with age.

One of the chief tests that is applied to Portland cement in order to ascertain its quality is to mix it with about 24 per cent of water and mold it into briquettes 1 square inch in area of cross section in the central part. These are placed in a machine and broken by a tensile strain which is measured. Good cement, when employed without the addition of sand, i. e., "neat" cement, should show a tensile strength of from 400 to 700 pounds or more per square inch when the briquettes are seven days old, and should slowly, but continuously, increase in strength with age. Tests of the tensile strength of Michigan cements are given on pages 681, 682.

USES.

Of the many uses of Portland cement only brief mention can be made at this time. As is well known, it is extensively employed in place of mortar and natural cement in nearly all masonry work, especially in large structures. Mixed with clean gravel, crushed stone, etc., in the proportion of about one part cement to five to seven of gravel or other suitable material, together with about four parts sand, and a suitable quantity of water, it forms concrete which is used in making the foundations for heavy machinery, buildings, light-houses, piers and abutments of bridges, entire arched bridges in some instances, the walls of houses, tanks for holding petroleum, etc. When used for such purposes the concrete is poured into molds of the desired shape, consisting usually of boards sustained on suitable frames, and allowed to harden. Concrete grading upward into sand cement is extensively used in making sidewalks, cellar floors, etc. It is also employed as a coating for masonry and especially brick walls, to exclude moisture, as in the lining of cisterns, the walls of cellars, etc. It is manufactured into artificial stone blocks, which are either solid, when designed for foundations, sea walls, etc., or hollow, when they are to be used in making the walls of dwellings, floors, etc. The desirability of cement for use in constructing buildings, and especially dwellings, lies in its cheapness as compared with stone, its pleasing gray color, resistance to fire (although it will not withstand a high degree of heat without crumbling), its slow response to changes of temperature, durability, cleanliness as respects vermin, etc. In fact the many advantages of cement for the construction of houses makes it probable that it will be largely used for that purpose, although but little advance has yet been made in this direction in the United States. The predicted scarcity of wood as a result of the destruction of the forests in the United States will apparently favor the employment of cement as a substitute. Portland cement has also been used in making sewers, drainpipes, culverts, curbings, fence posts, monuments, casts of works of art, etc. An instructive fact in connection with the many and various uses of cement is that in the extensive alterations in progress for the purpose of straightening and otherwise improving the Michigan Central Railroad, nearly, if not all, the new abutments of bridges were made of Portland cement concrete, which was laid in cold as well as warm weather with satisfactory results.

MATERIALS USED.

The raw materials which enter into the composition of Portland cement thus far used in Michigan are limestone, marl, shale, clay, gypsum, and fuel.

LIMESTONE.

Although limestone is abundant in Michigan, it usually contains a high percentage of magnesia, and in only a few instances has it been found to be sufficiently pure to be used in the manufacture of Portland cement. Thus far only two geological terranes, namely, the Dundee limestone and certain layers in the Traverse group, have been utilized for this purpose.

DUNDEE LIMESTONE.

This formation occurs at the base of the Devonian system, and although usually concealed beneath glacial drift and surficial deposits, comes to the surface, as is indicated on the map (Pl. XLIV), in a belt from about 2 to 9 miles wide, trending northeast and southwest across Wayne, Monroe, and Lenawee counties, in the southeastern corner of the State. The same formation occurs also at the extreme northern end of the Southern Peninsula and on Mackinac and neighboring islands, as well as in the adjacent portion of the Northern Peninsula. The purest layer of limestone in the Dundee thus far discovered is extensively quarried at Sibley and Bellevue, near Trenton, in Wayne County, and is used in the manufacture of sodium bicarbonate, soda ash, and caustic soda, near Detroit. The finely powdered calcium carbonate, resulting as a by-product from the manufacture of caustic soda, is used by the Michigan Alkali Company for making Portland cement at Wyandotte. This same limestone, on account of its unusual purity, is also extensively used in the manufacture of beet sugar.

The Dundee formation contains several beds of limestone, most of which, however, carry too high a percentage of magnesia to permit of their use in making Portland cement under the standard now required in the composition of the finished product. Thus far only one layer, the celebrated 9-foot bed, best exposed at the Sibley quarries, described below, has been found sufficiently pure to be utilized in the industries mentioned above. The composition of the rock quarried at Bellevue and used by the Michigan Alkali Company at Wyandotte is as follows:

Analysis of limestone of the Dundee formation at Bellevue.

[Analyst, O. Button.]

	Per cent.
Silica, SiO_2	0.60
Iron oxide, Fe_2O_3 } Alumina, Al_2O_3 }	3.04
Calcium carbonate, $CaCO_3$	95.24
Magnesium carbonate, $MgCO_3$	1.00
Total	99.88

The limestone of the Dundee formation is also quarried 2 miles northeast of Dundee, Monroe County, where four layers of limestone are exposed, the composition of which is shown below:

Analyses of Dundee limestone from the "Christiancy quarry" near Dundee.[a]

[Analyses 1, 3, 5, and 6 by G. A. Kirschmeier, and analyses 2 and 4 by K. J. Sundstrom.]

	Number of analysis and designation of bed.					
	1A.	2A.	3B.	4B.	5C.	6D.
Silica, SiO_2	0.48	0.70	1.10	1.86	2.78	0.81
Calcium carbonate, $CaCO_3$	90.80	98.10	86.80	86.96	77.60	95.00
Magnesium carbonate, $MgCO_3$	6.87	.63	11.60	10.08	17.41	3.86
Iron oxide, Fe_2O_3	.16		.12	} .62	{ .56	.41
Alumina, Al_2O_3						
Sulphur, S		.055		1.23		
Organic matter	1.69				1.63	
Difference	.00	.515	.38	.357	.02	.08
Total	100.00	100.00	100.00	100.00	100.00	100.00

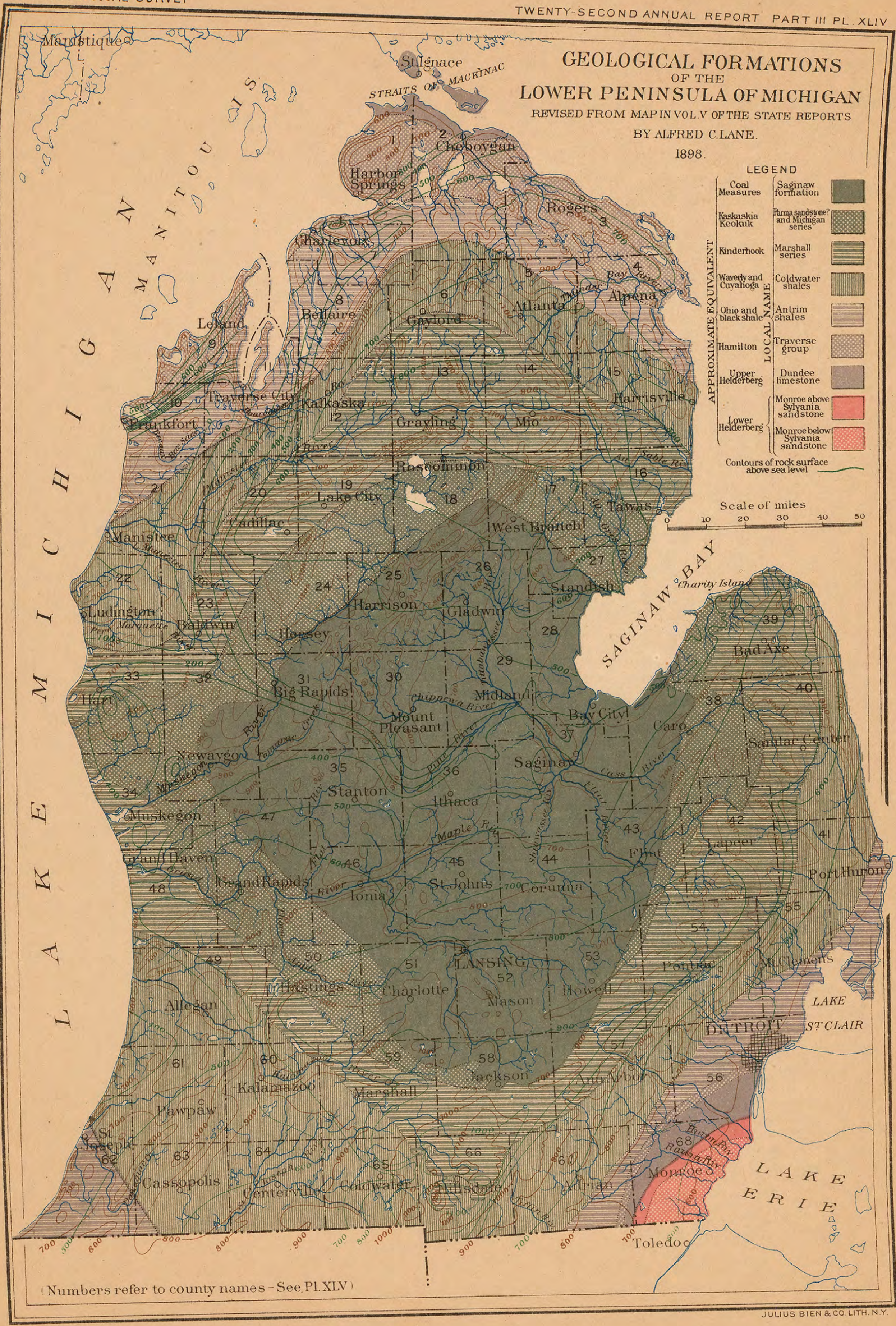
Bed A is uppermost; a gray limestone 1 to 2 feet thick, fossiliferous.
Bed B is a compact brownish limestone, bituminous, 4 to 4½ feet thick, fossiliferous.
Bed C is a soft, dark-gray limestone, without seams, 7 to 8 feet thick.
Bed D is similar to bed C, 8 feet thick; bottom of quarry.

The rocks exposed in the quarry near Dundee are considered by Sherzer as the identical layers that are extensively quarried near Trenton. When sufficiently low in magnesia the beds are evidently favorable for use in making Portland cement, the only questionable features seeming to be the expense of quarrying and crushing. Certain of the layers at Dundee contain petroleum, the influence of which on the mixing of slurry is not known.

The following notes concerning the Sibley quarry at Trenton, Wayne County, have been kindly furnished by Mr. Frank Leverett.

The quarry occupies an area of 35 acres. The rocks dip westward at the rate of about 5 feet in 100. There is a low anticlinal arch trending approximately east and west, which passes through the midst of the excavation, from the crest of which the beds dip away at the rate of about 1 foot in 100. The strata are cut by two systems of joints, bearing about N. 20° E. and N. 60° E. The quarry is situated in an irregular hill which rises about 30 feet above the level of the adjacent portion of Detroit River. On the higher portions of the hill there is no covering of drift, but on the sides the solid rock is concealed beneath several feet of till. Where the glacial deposits have

[a] W. H. Sherzer, Geological Report on Monroe County, Michigan: Geol. Survey Michigan, Vol. VII, Pt. I, 1900, pp. 75–76, 177–178.


GEOLOGICAL FORMATIONS
OF THE
LOWER PENINSULA OF MICHIGAN
REVISED FROM MAP IN VOL.V OF THE STATE REPORTS
BY ALFRED C. LANE.
1898.
LEGEND
APPROXIMATE EQUIVALENT
LOCAL NAME
Coal Measures
Saginaw formation
Kaskaskia Keokuk
Parma sandstone? and Michigan series
Kinderhook
Marshall series
Waverly and Cuyahoga
Coldwater shales
Ohio and black shale
Antrim shales
Hamilton
Traverse group
Upper Helderberg
Dundee limestone
Lower Helderberg
Monroe above Sylvania sandstone
Monroe below Sylvania sandstone
Contours of rock surface above sea level
Scale of miles
0 10 20 30 40 50
LAKE MICHIGAN
MANITOU IS.
STRAITS OF MACKINAC
SAGINAW BAY
LAKE ST. CLAIR
LAKE ERIE
Manistique
St. Ignace
Cheboygan
Harbor Springs
Rogers
Charlevoix
Alpena
Atlanta
Gaylord
Bellaire
Leland
Traverse City
Kalkaska
Harrisville
Frankfort
Grayling
Mio
Roscommon
Lake City
Tawas
Cadillac
West Branch
Manistee
Standish
Charity Island
Harrison
Gladwin
Ludington
Baldwin
Hersey
Bad Axe
Hart
Big Rapids
Midland
Mount Pleasant
Bay City
Caro
Sanilac Center
Newaygo
Saginaw
Stanton
Ithaca
Muskegon
Flint
Lapeer
Grand Haven
Grand Rapids
Ionia
St. Johns
Corunna
Port Huron
Pontiac
Mt. Clemens
Hastings
Charlotte
LANSING
Mason
Howell
Allegan
DETROIT
Jackson
Ann Arbor
Kalamazoo
Marshall
Pawpaw
St. Joseph
Monroe
Cassopolis
Centerville
Coldwater
Hillsdale
Adrian
Toledo
(Numbers refer to county names - See Pl. XLV)

been removed the surface of the rock beneath is intensely glaciated. There are two sets of glacial grooves, of which the earlier bears about S. 28° W. and the later approximately N. 30° W.

The strata exposed in the quarry are as follows, beginning at the surface:

Section at Sibley quarry, Wayne County, Mich.

	Feet.
1. Thin-bedded gray limestone, suitable for use as a flux	3.5
2. "Upper 6-foot bed," a gray limestone, containing 96 per cent $CaCO_3$; used in alkali works; a portion of the lower part of the bed, about 8 inches in thickness, is now rejected on account of its containing too much bituminous matter	6
3. Fossiliferous blue-gray limestone, containing 90 per cent $CaCO_3$; suitable for use in alkali works	3
4. "Second 6-foot bed," a blue-gray limestone, containing from 94 to 95 per cent $CaCO_3$; used as a building stone and in alkali works	6
5. "Five-foot bed, very similar to "Upper 6-foot bed"	5
6. "Cherty bed," a cherty limestone, not at present utilized	2
7. "Third 6-foot bed," a blue-gray limestone with a little chert in its lower portion; used in alkali works and as a building stone	6
8. "Nine-foot bed," a fossiliferous gray limestone; used in the manufacture of beet sugar and suitable for making Portland cement	9
9. "The 6-foot Magnesian limestone," dove colored	6
10. "The 8-foot bed," a thick-bedded gray limestone; used as building stone	8
11. "The 10-foot bed," a gray limestone of which the upper 3 feet contains about 85 per cent, the next 3 feet 95 per cent, and the lower 4 feet about 80 per cent $CaCO_3$; the lower portion contains from 3 to 4 per cent SiO_2; the middle portion of the bed is very fossiliferous	10
12. Brownish limestone containing 15 per cent SiO_2, .5 per cent MgO, and about 85 per cent $CaCO_3$; this rock is marked with white spots, thought to be aluminum silicate; used as building stone; opened to a depth of about	4
Total	63.5

Chemical analyses of certain of the beds described above are given below:

Analyses of limestone from Sibley quarries.

[Analyst, K. J. Sundstrom.]

Constituent.	5. South part of quarry.	5. North part of quarry.	6.	8. Upper part.	8. Central part.	8. Lower part.	9.	10.	11. Central part.
Calcium carbonate, $CaCO_3$	95.50	99.26	93.28	97.33	99.00	95.62	80.04	89.05	95.00
Magnesium carbonate, $MgCO_3$	2.36	.21	4.11	1.84	.22	3.15	15.96	8.08	4.00
Alumina, Al_2O_3	.30	Trace.	.40	Trace.	Trace.	Trace.	2.70	Trace.	Trace.
Silica, SiO_2	1.04	.50	1.90	.64	.54	.96	1.02	2.20	.56
Total	99.20	99.97	99.69	99.81	99.76	99.73	99.72	99.33	99.56

TRAVERSE GROUP.

The rocks designated by this name consist principally of shale and limestone, occur in succession next above the Dundee formation, and belong to the Devonian system. They form a belt, about 2 miles wide, which crosses Wayne and Monroe counties, as is indicated on Pl. XLIV, but are there concealed beneath surficial deposits, and also form a broad area which crosses the northern end of the Southern Peninsula from Alpena, on the border of Lake Huron, to Frankfort, on the shore of Lake Michigan. The limestone of the Traverse group comes to the surface at Alpena, and is utilized by the Alpena Portland Cement Company. In the quarry where it is well exposed it is a light-colored compact rock, carrying corals and other fossils. Its composition is as follows:

Analyses of limestone from the quarries of the Alpena Portland Cement Company, Alpena. [a]

[Analyst, F. H. Haldeman.]

Constituent.	1.	2.	3.	4.	5.	6.	7.	8.	9.
Silica, SiO_2	0.36	1.77	0.33	0.38	1.38	1.64	1.46	0.42	0.68
Calcium carbonate, $CaCO_3$	95.91	89.10	98.37	98.03	96.35	96.50	96.92	98.04	98.03
Magnesium carbonate, $MgCO_3$	3.63	8.67	.92	1.36	.94	1.26	1.46	.98	1.05
Iron oxide, Fe_2O_3 } Alumina, Al_2O_3 }	.13	.35	.18	.19	1.21	.27	.54	.18	.26
Total	100.03	99.89	99.80	99.96	99.88	99.67	99.90	99.72	100.02

1. Quarry C: Shell to be removed on stripping; 1 to 2 feet thick.
2. Quarry C: Top stratum, 2 feet thick.
3. Quarry C: Second stratum, 2 feet thick.
4. Quarry C: Third stratum, 4 feet thick.
5. Quarry C: Fourth stratum, 2 feet thick.
6. Quarry F: First stratum, 2 feet thick.
7. Quarry F: Second stratum, 1 foot thick.
8. Quarry F: Third stratum, 2 feet thick.
9. Quarry F: Fourth stratum, floor of quarry.

All samples show traces of sulphates and phosphates.

The favorable results in the manufacture of Portland cement obtained from the use of the limestones just considered will no doubt stimulate further search for favorably situated outcrops of the same formations, in which the accompanying map, showing where they may be expected to occur, will be of assistance.

SILURIAN LIMESTONES.

Occurring in geological succession below the Dundee limestone are formations of Silurian age, which contain thick beds of limestone.

[a] The Michigan Miner (Published at Saginaw, Mich.), Vol. III, No. 2, 1901, p. 22.

These rocks underlie nearly the whole of the Southern Peninsula, and come to the surface in the southeastern portion of the State, as indicated on Pl. XLIV, and are there known as the Monroe formation. These rocks also outcrop over a considerable portion of the Northern Peninsula, bordering Lakes Huron and Michigan, extending in a belt about 30 miles wide from Drummond Island and St. Marys River on the east to Green Bay on the west.

The rocks of the Monroe formation are extensively quarried in the southeastern portion of the State,[a] but nearly always contain a high percentage of magnesia, and in fact are usually dolomites. So far as known they are not suitable for use in making Portland cement, but need much more careful study, especially in the Northern Peninsula, before a sweeping conclusion concerning them in this connection would be justifiable. The Silurian beds here referred to are in part the equivalent of the Waterlime formation, extensively utilized in New York and elsewhere in the manufacture of natural cement.

MICHIGAN SERIES.

Another formation containing limestone, present in southern Michigan, is designated as the Michigan series on the map (Pl. XLIV), and belongs to the Eocarboniferous or Mississippian system. The limestones occur principally in the upper portion of the system and outcrop on the borders of the coal-bearing rocks which form the surface. They are in great part concealed by glacial drift and other surficial rocks over an extensive area in the central part of the Southern Peninsula.

The limestone of the Michigan series outcrops at Bayport and Sebewaing, in Huron County, on the east side of Saginaw Bay; on the Charity Islands; at Bellevue, in the southwestern part of Eaton County; and near the Portage River, about 5 or 6 miles north of Jackson. Other localities where it is accessible no doubt occur. It has been quarried at Bayport, Bellevue, and near Jackson, and calcined to make lime. Its composition, as indicated by the following analyses (stated as published), is such as to make it suitable for use in the manufacture of Portland cement, but up to the present time it has not been utilized for this purpose.

[a] Information concerning the rocks referred to above may be found in Rept. Geol. Survey Michigan, Vol. III, Pt. I, 1876, pp. 23, 27, and map; and Vol. VII, Pt. I, 1900, pp. 79–100, 174–177.

A map showing the distribution of the Silurian formations, particularly in the Northern Peninsula, forms Pl. XXII of the Fifth Ann. Rept. U. S. Geol. Survey, 1885.

Analysis of limestone from Bayport. [a]

[Analyst, J. W. Langley.]

	Per cent.
Silica	3.330
Oxide of iron and alumina	1.334
Carbonate of magnesia	.944
Carbonate of lime	91.538
Phosphorus and sulphur	Trace.
Organic matter and loss	2.854
	100.000

(Quicklime, 51.29.)

Analysis of limestone from Bellevue. [b]

[Analyst, Carl Rominger.]

	Per cent.
Carbonate of lime	96.00
Carbonate of magnesia	1.00
Hydrate of iron oxide	.50
Insoluble residue	1.50
	99.00

Analysis of limestone from Portage River. [c]

[Analyst, Carl Rominger.]

	Per cent.
Carbonate of lime	96.90
Carbonate of magnesia	1.00
Alumina and iron	.70
Insoluble residue	1.40
	99.00

On consulting the reports referred to above, it will be found that the limestone of the Michigan series contains layers that are high in magnesia or are otherwise unfavorable for cement making, but in spite of this the formation is evidently worthy of careful attention from persons interested in the industry under review, wherever it occurs near deposits of clay or shale and is suitably situated in reference to transportation facilities, etc.

All of the limestones referred to above are of marine origin and usually contain fossils, among wnich coral is frequently conspicuous. The rocks are usually compact and hard, and if employed in the manufacture of Portland cement must be crushed and ground to a fine powder. Except for the expense thus involved they are in certain instances as favorable for the use indicated as the marls described below.

MARL.

The term marl is loosely used, and while supposed to refer to an indefinite mixture of calcium carbonate and clay, is so generally employed to designate the nearly pure deposits of calcium carbonate

[a] Geol. Survey Michigan, Vol. III, Pt. I, 1876, p. 84.
[b] Ibid., p. 113.
[c] Ibid., p. 117.

here considered, that it is seemingly impracticable to adopt any other name for them at this time.[a] The deposits referred to occur in abundance throughout the Southern Peninsula and are known to be present also to the north of the Strait of Mackinac. They usually occupy lakes and swamps and in many instances are still in process of formation. Geologically they are all recent and for the most part occupy depressions in glacial drift.

The abundance of marl in Michigan has been known for many years, and its value as a fertilizer was pointed out particularly by Douglas Houghton and Alexander Winchell, former State geologists. In the first report made by Houghton to the governor of Michigan, 1837, a manuscript copy of which may be found in the library of the University of Michigan, the following passage occurs: "The State abounds in deposits of marl, composed of recent shells, which in some few instances has been used in the manufacture of lime. Inexhaustible beds exist in the northern part of St. Joseph and the adjoining counties, and as a manure it will be invaluable to the agricultural interests of those portions of the State. Several extensive beds were seen in Jackson County and also in Monroe County, near the city of Monroe."

The early recognition of the character and value of the marl accumulations referred to is shown by the following statements by Winchell, in a paper on "The Shell Marls of Michigan," published in the Michigan Farmer in 1855.[b] It is of interest to note that in this article the material under consideration is termed "shell marl," and its accumulation referred principally to the agency of mollusks.

Thus the lakes and ponds were formed. These then became the abodes of innumerable aquatic animals and plants. How many successive generations lived and perished in these waters and about their shores it is impossible to say, but in the course of ages the débris of animal and vegetable life began to create sensible accumulations upon the bottoms and margins of these lakes. Plants grew up and perished. The materials which had nourished and formed them, derived partly from the air, partly from the water, and partly from the earth, were deposited in the common bed, which thus gradually increased. Fish and reptiles mingled their remains with those of their congeners, but especially the tribes of shellfish or molluscous animals contributed their hard and calcareous coverings to the general accumulation. By degrees the lakes were filled up. The prevalence of strong westerly winds drifted these effete materials to the leeward shores, where the accumulations were much the most rapid. On those shores the water became at first shallow, and furnished a habitat for numerous additional species of plants. Then the water became too shallow to be much frequented by aquatic animals and became a marsh. As animal remains diminished in quantity vegetable remains increased. Finally vegetable life required undisputed possession, and since that time unnumbered generations of plants have flourished and decayed above those ancient depositories of the common tenants of the waters. In the meantime the process of encroachment upon the waters from the leeward shores has been continued. At the bottom lie

[a] As will be shown later, the marl of Michigan and of other localities is so definitely a result of the vital action of certain algæ, and especially of the *Characeæ*, that it might justly be termed *charite*.

[b] Vol. XIII, pp. 257-259.

mostly shells and animal remains, because these deposits were formed mainly while the water prevailed. Upon these lies a mixture of débris from both kingdoms, deposited while the spot was a submerged marsh, and above the whole rests a bed of dark-brown vegetable matter, in which the stems and roots of ancient plants can be distinctly traced. In many instances these accumulations have supplanted the entire waters of a lake, and nothing remains but a swamp, a marsh, a swale, or in some cases dry and beautiful meadow lands. In other instances the encroachment has created a swamp on the east or southeast, faced by a lake on the west or northwest. In the natural course of events these lakes will all become marshes and the marshes dry and valuable land.

The first deposits from the tenants of these lakes formed the marl beds of the State—the subsequent ones from aquatic and marsh plants constitute the peat beds which almost everywhere overlie the marl.

The marl is composed mainly of comminuted shells. Many unbroken specimens of minute size may however be picked out. In the neighborhood of the transition line between the marl and peat the perfect shells are of larger size and more abundant. In the lower portion of the peat they constitute a large percentage. These shells are an abundant source of carbonate of lime. They belong mostly or entirely to species still existing in the adjacent waters.

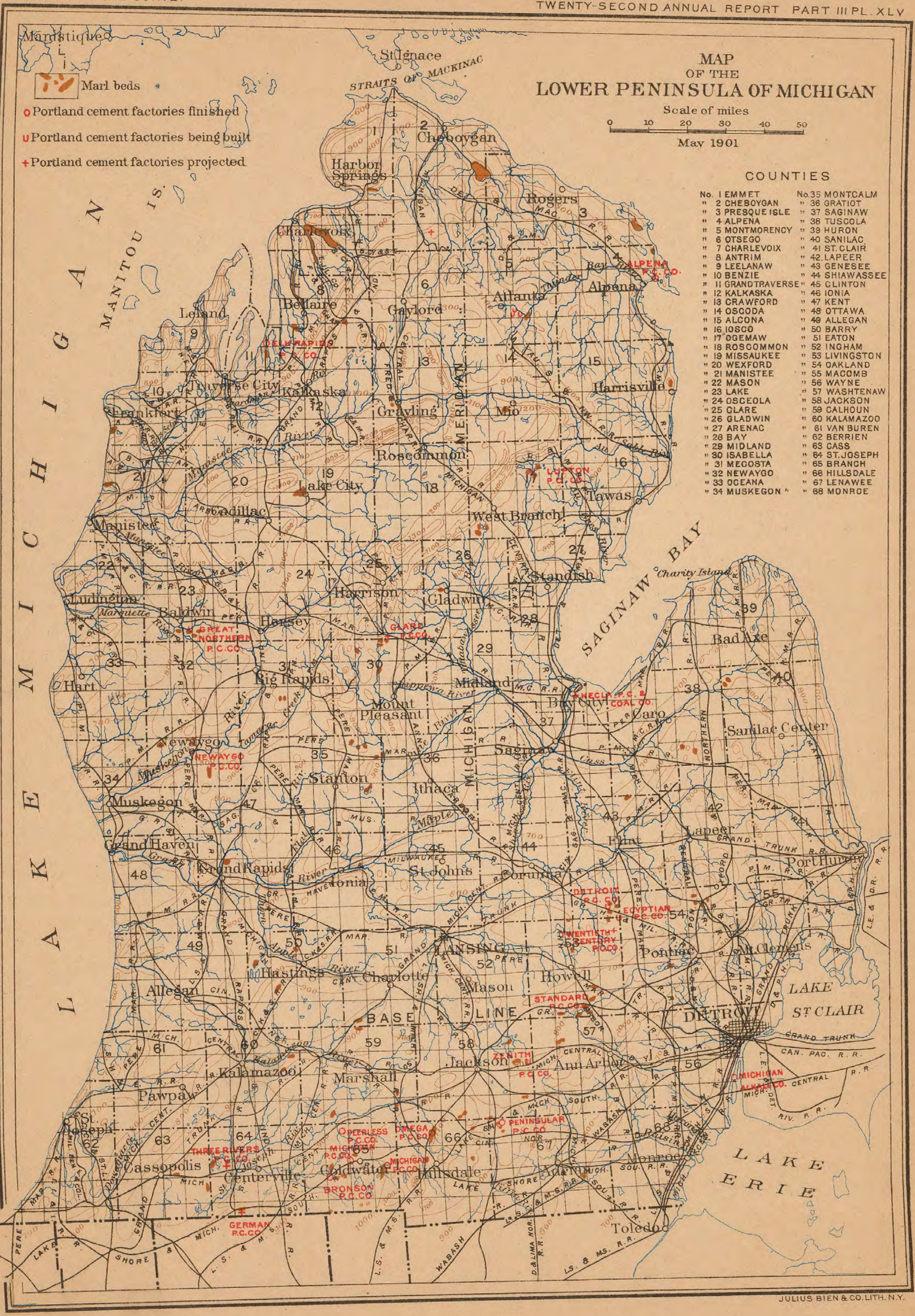
The marl is a genuine shell marl, and exceedingly valuable as a fertilizer. The peat is of a spurious kind, but when judiciously employed, its abundance of vegetable matter will render it a mine of wealth to the agricultural interests of the State.

In continuance, Winchell presents the results of a physical and chemical examination of a sample of marl from near Howell in Livingston County.

MODE OF OCCURRENCE.

Some idea of the abundance and wide distribution of marl deposits in the Southern Peninsula may be obtained from the map (Pl. XLV), on which those it has been convenient to locate are indicated. This is by no means a complete index of the total number of marl deposits that occur in the area represented, as it has not been found practicable to make a detailed survey for the purpose of mapping them. It is safe to say that those shown on the map are probably less than one-fourth of the total number that exists in the Southern Peninsula. Those indicated on the map, with possibly a few exceptions, have an area in excess of 50 acres, and an average depth of 10 feet or more.[a] The marl beds of Michigan only are considered in this report, but deposits of the same character are known to occur in neighboring States, as well as in the adjacent portions of Canada, but their entire distribution and their precise relation to climatic and geological conditions, etc., have not been determined. In extent the marl beds vary from a few acres up to several hundred acres. Some of the Portland cement companies, it is stated, have marl beds from 500 to 1,000 acres in area, with an average depth of 20 feet or more. In most instances these figures probably refer to two or more separate but perhaps closely adjacent beds. It is safe to say, however, that single beds

[a] In the compilation of the data shown on Pl. XLV, I have been assisted by Dr. A. C. Lane, State geologist, Prof. C. A. Davis, of Alma College, and others.


MAP
OF THE
LOWER PENINSULA OF MICHIGAN
Scale of miles
0 10 20 30 40 50
May 1901
Marl beds
Portland cement factories finished
Portland cement factories being built
Portland cement factories projected
COUNTIES
No. 1 EMMET
" 2 CHEBOYGAN
" 3 PRESQUE ISLE
" 4 ALPENA
" 5 MONTMORENCY
" 6 OTSEGO
" 7 CHARLEVOIX
" 8 ANTRIM
" 9 LEELANAW
" 10 BENZIE
" 11 GRAND TRAVERSE
" 12 KALKASKA
" 13 CRAWFORD
" 14 OSCODA
" 15 ALCONA
" 16 IOSCO
" 17 OGEMAW
" 18 ROSCOMMON
" 19 MISSAUKEE
" 20 WEXFORD
" 21 MANISTEE
" 22 MASON
" 23 LAKE
" 24 OSCEOLA
" 25 CLARE
" 26 GLADWIN
" 27 ARENAC
" 28 BAY
" 29 MIDLAND
" 30 ISABELLA
" 31 MECOSTA
" 32 NEWAYGO
" 33 OCEANA
" 34 MUSKEGON
No. 35 MONTCALM
" 36 GRATIOT
" 37 SAGINAW
" 38 TUSCOLA
" 39 HURON
" 40 SANILAC
" 41 ST. CLAIR
" 42 LAPEER
" 43 GENESEE
" 44 SHIAWASSEE
" 45 CLINTON
" 46 IONIA
" 47 KENT
" 48 OTTAWA
" 49 ALLEGAN
" 50 BARRY
" 51 EATON
" 52 INGHAM
" 53 LIVINGSTON
" 54 OAKLAND
" 55 MACOMB
" 56 WAYNE
" 57 WASHTENAW
" 58 JACKSON
" 59 CALHOUN
" 60 KALAMAZOO
" 61 VAN BUREN
" 62 BERRIEN
" 63 CASS
" 64 ST. JOSEPH
" 65 BRANCH
" 66 HILLSDALE
" 67 LENAWEE
" 68 MONROE
LAKE MICHIGAN
MANITOU IS.
STRAITS OF MACKINAC
SAGINAW BAY
LAKE ST. CLAIR
LAKE ERIE
Manistique
St. Ignace
Cheboygan
Harbor Springs
Charlevoix
Rogers
Alpena
ALPENA P.C. CO.
Atlanta
Bellaire
Gaylord
Leland
ELK RAPIDS P.C. CO.
Traverse City
Kalkaska
Frankfort
Grayling
Mio
Harrisville
Roscommon
Lake City
Cadillac
LUPTON P.C. CO.
Tawas
West Branch
Manistee
Standish
Charity Island
Ludington
Baldwin
Harrison
Gladwin
GREAT NORTHERN P.C. CO.
Hersey
CLARE P.C. CO.
Bad Axe
Big Rapids
Hart
Midland
HECLA P.C. & COAL CO.
Bay City
Mount Pleasant
Caro
Sanilac Center
Newaygo
NEWAYGO P.C. CO.
Saginaw
Stanton
Ithaca
Muskegon
Lapeer
Flint
Grand Haven
Port Huron
Grand Rapids
Ionia
St. Johns
Corunna
DETROIT P.C. CO.
EGYPTIAN P.C. CO.
TWENTIETH CENTURY P.C. CO.
Pontiac
Mt. Clemens
LANSING
Hastings
Charlotte
Howell
Allegan
Mason
STANDARD P.C. CO.
BASE LINE
DETROIT
Kalamazoo
Marshall
Jackson
ZENITH P.C. CO.
Ann Arbor
MICHIGAN ALKALI CO.
Pawpaw
St. Joseph
PENINSULAR P.C. CO.
PEERLESS P.C. CO.
OMEGA P.C. CO.
THREE RIVERS P.C. CO.
MICHIGAN P.C. CO.
Cassopolis
Centerville
Coldwater
Hillsdale
Adrian
Monroe
BRONSON P.C. CO.
GERMAN P.C. CO.
Toledo
MERIDIAN
MICHIGAN

from 100 to 300 acres in area and with an average depth of 20 feet or more are not rare.

In depth the marl beds vary from a few inches up to over 35 feet, as has been demonstrated by the writer by actual borings. Other observers report depths up to 50 and even in excess of 70 feet, which are no doubt reliable measures.

The marl beds occur principally in the basins of existing lakes, but frequently extend beyond the present water margins and underlie the bordering swamp. They are present also in many instances beneath beds of peat or muck, from a few inches to several feet thick, on which tamarack and other trees grow. The presence of marl beds about the borders of existing lakes and at an elevation in some cases of 10 or 15 feet above their surfaces shows that the lakes have been lowered, usually by the cutting down of their outlets since the marl began to form. In some examples peat occurs beneath extensive marl beds, and in a few cases two or three alternations of layers of peat and marl have been discovered.[a] Usually, however, there is but one bed of marl present, which rests on a sandy or clayey bottom. It is evident in all instances that the marl was deposited in a lake, and that the swamps, or in some instances the now well-drained tracts where it is found, were formerly flooded.

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[a] Geol. Survey Michigan, Vol. VII, Pt. II, 1900, p. 248.

Analyses of Michigan marl.

Locality.	Analyst.	SiO_2.	Al_2O_3.	Fe_2O_3.	CaO.	$CaCO_3$.	MgO.	$MgCO_3$.	SO_3.	Loss on ignition.	Organic matter.	Remarks.
Alpena	E. D. Campbell	8.13	3.06		43.09	[a]76.78	.54	[a]1.13	....	44.99	....	From lake about 7 miles north of Alpena.
Bronson	W. H. Simmons	1.75	1.57		[a]49.24	87.92	[a].44	.92	0.15	....	7.50	Used by the Bronson Portland Cement Company.
Coldwater	E. D. Campbell	.52	.51	.53	51.66	[a]92.25	1.37	[a]2.87	.89	....	....	Used by the Michigan Portland Cement Company.
Do	H. E. Brown	.15	.27	.19	46.20	[a]82.51	.88	[a]1.85	....	....	.05	CO_2 = 36.30 These two analyses show the extreme range in composition of the marl used by the Michigan Portland Cement Company at Coldwater.
Do	do	8.60	1.30	1.54	54.69	[a]97.52	2.78	[a]5.84	....	....	10.50	CO_2 = 42.90
Crapo Lake	Lathbury and Spackman.	1.46	.36		50.75	[a]90.62	1.46	[a]3.07	....	45.02	....	Furnished by the Hecla Portland Cement and Coal Company.
Fenton	E. D. Campbell	.48	.17	.51	52.28	[a]93.25	1.85	[a]3.88	.55	44.47	....	From Mud Lake, Shiawassee County. Furnished by Detroit Portland Cement Company.
Do	do	1.36	.55	.36	50.03	[a]89.34	1.95	[a]4.10	.69	45.72	....	
Do	do	.55	.14	.54	51.76	[a]32.15	1.90	[a]3.99	....	45.32	....	
Do	do	.90	.20	.39	51.57	[a]92.09	1.68	[a]3.52	.46	45.86	....	From Silver Lake, Shiawassee County. Furnished by Detroit Portland Cement Company.
Fourmile Lake	do	6.66	3.17	1.36	[a]47.09	84.09	[a]1.77	3.72	1.25	....	....	Near Chelsea, Washtenaw County.
Grayling Lake	R. C. Kedzie	1.90	.14	.10	45.16	[a]79.86	.32	[a].67	.56	....	5.69	Also: K_2O = 0.37; Na_2O = 2.65; CO_2 = 43.10; P_2O_5 = .01. Mich. Agr. Expt. Sta. Bull. No. 99, 1893.
Jackson	E. D. Campbell	2.73	1.21	.46	50.58	[a]90.32	1.61	[a]3.39	.39	....	....	From near Jackson.
Lime Lake	Dearborn Drug and Chemical Works, Chicago.	1.30	.70		[a]53.19	94.98	1.44	[a]3.02	Trace.	....	....	Near Lakeland, Livingston County. From Prospectus of the Standard Portland Cement Company.
Luddington	E. D. Campbell	1.85	.65	.40	51.83	[a]92.50	1.03	[a]2.16	.22	....	....	
Lupton	Lathbury and Spackman.	.24	.08		52.97	[a]94.58	1.13	[a]2.37	.08	45.49	....	In Ogemaw County. From Prospectus of the Lupton Portland Cement Company.
Do	do	.25	.19		52.28	[a]93.53	1.14	[a]2.39	.18	46.05	....	Do.
Mills Lake	do	.70	.46		50.43	[a]90.07	1.26	[a]2.65	....	47.08	....	In Ogemaw County. Furnished by Hecla Portland Cement and Coal Company.

[a] Computed from the analyses as reported.

Analyses of Michigan marl—Continued.

Locality.	Analyst.	SiO_2.	Al_2O_3.	Fe_2O_3.	CaO.	$CaCO_3$.	MgO.	$MgCO_3$.	SO_3.	Loss on ignition.	Organic matter.	Remarks.
Mosherville.....	(Not given)........	.91	.29		[a]52.15	93.12	[a]1.42	2.98	.31	....	2.13	Furnished by the Omega Portland Cement Company. Used by the Omega Portland Cement Company.
Do...........	E. D. Campbell	.20	.50	.60	50.12	[a]89.50	.83	[a]1.74	.58	45.86	....	Furnished by the Omega Portland Cement Company. Used by the Omega Portland Cement Company.
Pleasant Lake...	Lathbury and Spackman.	.84	.28		51.28	[a]91.57	1.77	....	....	45.60	....	Near Three Rivers. Furnished by Three Rivers Portland Cement Company.
Plummer Lake..	.....do..............	1.78	.61		52.38	[a]93.53	1.49	[a]3.13	....	44.31	....	In Ogemaw County. Furnished by Hecla Portland Cement and Coal Company.
Runyan Lake ...	E. D. Campbell	.28	.65	.67	52.66	[a]94	1.75	[a]3.67	.38	42.44	....	Near Fenton; in Livingston County.
Union City......	A. Lundteigen......	1.95	1.10		52.25	[a]93.32	....	....	....	42.40	....	Moisture and organic matter in air-dried sample, 13.95 in first and 4.97 in second analysis. These two analyses show range in composition of marl used by Peerless Portland Cement Company.
Do...........	.....do..............	.50	.66		44.95	[a]80.32	....	....	....	36.30	....	
Wetzell..........	E. D. Campbell	1.44	.28	.16	51.93	[a]92.75	1.15	[a]2.41	.034	44.25	....	From Lake Wetzell, Antrim County.
Do...........	.....do..............	.82	.49	.36	52.94	[a]94.53	.92	[a]1.93	.15	44.50	....	Do.
White Pigeon....	H. A. Huston	37	.56		51	[a]91.09	1.02	[a]2.14	....	....	4.01	Also: $K_2O = 0.17$; $Na_2O = 0.52$; $CO_2 = 40.08$. Sulphates = trace. From Prospectus German Portland Cement Company.
Woodstock	J. G. Dean	.38	.68		50.76	[a]90.66	.86	[a]1.81	Trace.	46.62	....	From Goose Lake, Lenawee County. Used by the Peninsular Portland Cement Company.
Zukey Lake.....	E. D. Campbell	.96	....	.62	[a]52.60	[a]93.92	1.79	[a]2.76	.58	....	....	In Livingston County. Furnished by the Standard Portland Cement Company.
Do...........	Dearborn Drug and Chemical Works, Chicago.	1.30	.58		52.93	[a]94.52	1.44	[a]3.02	Trace.	....	....	Do.

[a] Computed from the analyses as reported.

The marl beds occur for the most part in depressions in glacial drift, both morainal and fluvioglacial, and in the channels of streams, now partially filled, which flowed away from the last ice sheet of the Glacial epoch as it withdrew; that is, they occupy depressions in the sheet of surficial material left by the retreat of the ice during the Wisconsin stage of the Glacial epoch. In general, the marl beds are above the limit reached by the Great Lakes during their highest stage, but there are a number of exceptions to this rule. The reason for the greater abundance of marl beds above than below the reach of the Great Lakes during their higher stages in various basins is because the country flooded was to a great extent smoothed over by lacustral deposits and local depressions were obliterated. By far the greater number of the marl beds in the Southern Peninsula of Michigan that occur below the level of the higher beaches left by the Great Lakes during the former high-water stages are located in its northern portion, beyond the reach of the waters of its glacial lakes, Maumee, Warren, and Chicago, where the land presumably was submerged for a shorter time than at the south.

Many of the existing lakes in which marl occurs have an abundant inflow and outflow, but others have but small if any visible tributaries, and small, and, in some cases, no surface outflow. As will be indicated later, there is evidently no causal relation between the presence of marl in a lake basin and the volume of the inflowing or outflowing water. The marl is found principally about the margins of the lakes in which it occurs, and frequently forms a well-defined submerged terrace with a surface sloping very gently from the shore outward and with a precipitous lakeward descent on its outer border. These terraces are frequently from 100 to 500 feet or more broad; their outer margins are usually covered by 10 to 12 feet of water and descend by slopes of perhaps 35° into water that is from 30 to 50 feet deep. The thickness of the marl in such instances rapidly increases from a few inches, near the shore, or, in case the lake has shrunken since the marl began to be deposited, some distance landward, to 35 feet or more in the middle and outer portions of the terraces. As the beds of the lakes beneath the marl are frequently irregular and hummocky, many variations in the thickness of the marl terraces occur.

At times the marl forms spits and bars, due in part to the action of waves and currents, which occasionally divide a basin into two or more lakes. In this manner what may be termed "daughter lakes" have originated about the sides, but more frequently at the ends of long narrow lakes; or a lake has been divided into several individual water bodies, separated by marly or peaty deposits. The lakes with terraces are frequently surprisingly deep for their areas. In many instances a depth of 50 feet or more occurs in a lake that is only 200 or 300 yards across. Marl frequently occurs also over the entire bottom of the lakes, whether marl terraces are present or not; but such observations as are available show that in water over 20 feet deep it is usually exceedingly fine and highly charged with organic matter. The full depth of marl in the bottom of the deeper lakes has as yet not been determined, for the reason that when covered by more than 20 feet of water it is usually considered as being commercially unavailable. Even in the deeper lakes there are frequently islands and shoals composed of marl, perhaps an acre or two in area, which rise from water 40 to 50 feet deep, the marl being from 20 to 30 feet or more in depth. These elevations on the lake bottoms are frequently entirely surrounded by deep water, and give evidence that the marl composing them was formed where it is now found and is not due to the accumulation of material by currents.

In lakes in which a large area is occupied by marl, perhaps 20 feet or more in depth, there is frequently an abrupt transition from nearly pure marl to nearly pure peat. Even on the marl terraces referred to above there is sometimes a change in the space of a few hundred feet measured in the direction of the lake's shore from perhaps 20 feet or more of clear marl to as great a depth of black peat or muck. These variations in the distribution, depth, etc., of the marl in an individual basin not only have a bearing on the commercial importance of the deposit, but are of interest in reference to the origin of the marl itself, as will be shown later.

PHYSICAL PROPERTIES.

The marl of Michigan is of two quite well-defined varieties, namely, white and gray, although there is no sharp distinction between them. The variation in color depends mainly on the amount of organic material present, but in some cases a gray color is due to a greater or less percentage of clay, which is absent from the white marl.

The white marl is nearly pure white, although frequently having a yellowish tint when wet. The purest deposits are almost as white and fine as wheat flour. They contain only occasional shell fragments, and are without the concretion-like kernels and nodules which give character to other deposits of the white variety. The gray marl, at times rendered impure on account of the presence of clay, is a soft, homogeneous, fine-grained substance, resembling a light-colored mud. Each variety of marl usually contains fresh-water shells, such as *Planorbis*, *Limnea*, *Succinea*, *Unio*, *Anodonta*, etc., either entire or, what is more frequent, broken into fragments, of which a large number of species have been identified.[a] Except near the surface, however, where the dead shells have been accumulated through the action of waves and currents, they usually form only a small percentage of the

[a] Shells of the marls of Huron County, by Bryant Walker, Geol. Survey Michigan, Vol. VII, Pt. II, 1900, pp. 247-252. The list given contains 34 genera and about 120 species.

deposits. There is an easily recognizable gradation in the character of the shell fragments from the surface downward. Below a depth of about 10 or 15 feet the shells have for the most part become thoroughly disintegrated. The proportion of shells seldom exceeds 5 per cent for any considerable body of the material, and for this reason it can not be justly termed shell marl.

Near the margins of the marl lakes there is frequently an admixture of marl and gravel, sand, clay, etc., dependent on the character of the adjacent banks; but the breadth of this bordering fringe is usually only a few feet or a few yards, except in certain instances when clays occur or when spits of gravel and sand extend outward from the shore. These impure fringes to the marl deposits frequently impair their commercial value. In some instances, however, there is a complete gradation from nearly pure marl in one portion of a lake basin through clayey marl and calcareous clay to clay containing only a small percentage of calcium carbonate. Dust blown into the lakes, except where fine sand forms their shores, has seldom furnished an appreciable portion of the marl beds contained in them.

When an average sample of the marl is subjected to a mechanical analysis—that is, passed through a series of sieves varying from 12 to 200 meshes to the linear inch—the material composing it is separated into various parts dependent on size. The results of two such analyses, one of a representative gray marl from Goose Lake, near Cement City, used by the Peninsular Portland Cement Company, and another of unusually pure white marl from Lake Wetzell, in Antrim County, are here presented. While the samples selected are representative, they do not embrace as wide a range in physical composition as might easily be obtained, for the reason that deposits of white marl, particularly, are in some instances largely composed of concretion-like nodules, as will be noted later.

Mechanical analyses of marl.

	Lake Wetzell.	Goose Lake.
	Per cent.	*Per cent.*
Residue on a 12-mesh sieve	0.00	1.62
Residue on a 50-mesh sieve	1.93	12.44
Residue on a 100-mesh sieve	6.50	16.55
Residue on a 200-mesh sieve	7.99	11.76
Material passing through a 200-mesh sieve	83.66	56.63
Total	100.08	99.00

The fractional portions of the two samples of marl obtained by the mechanical analyses stated above, when examined with a microscope, a three-quarter inch objective and reflected light being used, gave the following results:

All the fractional portions of the Lake Wetzell marl were of snowy whiteness. The portions remaining on a 50-mesh sieve consisted mainly of irregular elongated grains with tubular centers, the walls of the tubes being circular and sometimes distinctly striated. Evidently these tubes were formed by the deposition of crystalline grains of calcium carbonate about vegetable stems, the vegetable matter having subsequently been removed. As will be discussed later, the stems about which the calcium carbonate was deposited were evidently of the genus *Chara*. At least 50 per cent of the material remaining on the 50-mesh sieve consisted of these white crystalline tubular deposits. About 30 per cent of the material was composed of shells and fragments of shells, with an occasional quartz grain. The remaining 30 per cent by estimate consisted of amorphous grains, apparently fragments of tubular incrustations like those mentioned above, together with an occasional vegetable fiber and a few fragments of the larval cases of insects. The portion passing through a 100-mesh sieve consisted almost entirely of material like that forming the major part of the portion described above, many of the grains being distinctly tubular. The shell fragments were less numerous and by estimate did not exceed 5 per cent. The portion remaining on a 200-mesh sieve was nearly pure calcium carbonate in irregular grains, many of which were traversed by tubular openings. Most of the tubes showed smooth walls, while others were distinctly striated on the interior. In all cases the outsides of the tubes were irregular, their walls being as thick as or in some cases of greater thickness than the diameter of the tube within. A few shell fragments were also present, but by estimate less than 5 per cent, and an occasional fragment of the larval case of an insect could be recognized. Snow-white calcium carbonate combined with an occasional yellow grain made up at least 95 per cent of the material.

The material which passed through a 200-mesh sieve, that is, over 83 per cent of the original sample, consisted of amorphous and crystalline grains without visible structure.

The Lake Wetzell marl, when dissolved in hydrochloric acid, left a slight residue, in which irregular, minute grains were visible under a microscope with a one-quarter inch objective, but no diatoms were distinguished.

The fractional parts of the Goose Lake marl showed various shades of brown in the coarser portions, changing to light gray in the case of the powder which passed through a 200-mesh sieve. The coarser portions consisted almost entirely of fragments of vegetable stems, with a few shells and fragments of shells, but did not reveal distinct tubular aggregates of crystalline particles as in the case of the Lake Wetzell sample. The portion which passed through a 200-mesh sieve, or 56 per cent of the original sample, contained a large amount of fragments of vegetable matter mingled with seemingly structureless grains of snow-white calcium carbonate.

Partial mechanical analyses of samples of white marl from several lakes, of which Silver Lake, near Fenton, and Zukey Lake, near Hamburg, are representative, showed the presence of large numbers of concretionary-like masses of calcium carbonate, varying in size from a fraction of an inch up to an inch or more in diameter. These kernels and pebble-like bodies are rough and somewhat irregular, but in general are spheroidal, with the shorter axis perhaps one-fourth shorter than the longer axis. When broken across they reveal both a concentric and radiate structure. As these nodules occur in the lakes they are of a yellowish color and so soft that they may be crushed in the hand, but become nearly white or light gray and quite hard on drying. In some instances a grain of sand or a fragment of a shell may be found at the center of a nodule, but more frequently there is no distinguishable body about which the calcium carbonate was deposited. In some instances, as in Silver and Mud lakes, near Fenton, marl beds 30 feet or more thick occur which are composed almost entirely of pebbly masses of the nature just described.

In many marl lakes, also, the bottom is strewn with the detached valves of unio and anodon shells, or fresh-water clams, as they are commonly termed, which are incrusted with an irregular layer of calcium carbonate 2 inches or more in thickness. Both the oval nodules referred to above and the thick incrustations on the shells of unios, etc., are essentially of the same character and are not a detriment in the use of the marl for cement making, since they are easily crushed and ground to fine powder. All of these nodules and accretions when placed in acid effervesce actively and when the calcium carbonate is removed leave a gelatinous mass of algæ which retains about the original form of the nodule in which it was inclosed.

At times the marl has a gritty feeling, suggesting the presence of sand, but in most instances when it is treated with acid nearly complete solution takes place, which, together with examinations with the microscope, show that the grittiness is due to the presence of crystalline particles of calcium carbonate. The residues left on dissolving various samples of marl, when examined under the microscope, frequently show a large amount of vegetable stems, etc., particularly in the case of the gray marls, and also occasional sand grains, but sand does not enter largely into the composition of the deposits except in certain cases near their margins, as previously noted. In the residue also the minute siliceous cases of diatoms may frequently be distinguished. These, however, are seldom in great abundance, and in no case thus far discovered can they be considered as detracting from the value of the marl for cement making.

The marl frequently occurs in association with peat, and especially in marshes, is commonly overlain by that material to a depth of from a few inches to several feet, and all degrees of admixture of marl and peat may be obtained, although usually there is a sharp plane of division between the two. A peculiar and interesting feature of the marl and peat deposits already referred to is that when traced horizontally abrupt changes from one class of material to the other sometimes occur. That is, a bed of nearly pure marl, with a depth of 20 to 30 feet or more, in the space of a few yards may change to nearly pure peat of equal depth.

The specific gravity of dry marl is stated by Alexander Winchell to be 1.655.[a] As has been determined by E. D. Campbell, 1 cubic foot of wet marl as it usually occurs in the natural deposits contains 47.5 pounds of marl and 48 pounds of water.

CHEMICAL COMPOSITION.

Many chemical analyses of Michigan marl are available, and show that in general the marl is nearly pure calcium carbonate or carbonate of lime, $CaCO_3$, but contains a small per cent of magnesium carbonate, $MgCO_3$, and also of sulphuric anhydride, SO_3. Neglecting the usually thin borders of the marl deposits, where mechanical admixtures of material from the neighboring banks occur, and also the deposits commercially unavailable on account of the high percentage of organic matter they contain, the composition of the marl is fairly represented by the analyses given in the table on pages 650–651. The variation in composition that may be expected in different portions of the same deposit is indicated in the table by the two analyses by H. E. Brown of the marl used by the Michigan Portland Cement Company, near Coldwater, and by the two analyses by A. Lundteigen of the marl used by the Peerless Portland Cement Company, at Union City. In each of these examples the analyses have been selected from a large number, to show the range in composition.

ORIGIN.

As already stated, the marl occurs in depressions in the present surface of the land, usually in glacial deposits, and in numerous lakes is still in process of accumulation. The source of the calcium, magnesium, etc.—that is, of all the substances composing the marl except the mechanically commingled material—is clearly the water in which it was deposited. The surficial glacial formations of Michigan to the south of the central part of the Northern Peninsula contain large amounts of limestone, and the water percolating through them becomes more or less highly charged with mineral matter, largely calcium carbonate in solution. In other words, the water is "hard." The waters supplying the lakes reach them, to a great extent, by seepage from the adjacent hills and gravel plains, as well as from hillside springs and

[a] The Michigan Farmer, Vol. XIII, 1855, p. 258.

surface streams, and contain calcium carbonate in solution. Analyses of the waters of a large number of streams and lakes in the Southern Peninsula are available,[a] from which a fair judgment as to the average composition of the waters of the marl lakes may be obtained. The analyses of the waters of twelve representative lakes presented in the report just referred to give the following averages, expressed in parts per thousand:

Average analyses of water of twelve representative lakes.

Calcium carbonate, $CaCO_3$	.113
Calcium sulphate, $CaSO_4$	.043
Oxides of iron and alumina, Fe_2O_3 and Al_2O_3	.006
Magnesium carbonate, $MgCO_3$	.074
Magnesium sulphate, $MgSO_4$	.033
Sodium and potassium carbonate, Na_2CO_3 and K_2CO_3	.020
Sodium and potassium chloride, NaCl and KCl	.023
Silica, SiO_2	.023
Organic matter	.019
Total	.357

In the report just referred to[b] a series of twenty-two analyses of water from marl-depositing and other lakes, wells, and outlet streams from lakes, collected near Cloverdale, Barry County, were made by A. N. Clark, with the following average results:

Calcium carbonate ($CaCO_3$), from 0.030 to 0.217 part per 1,000.

Magnesium carbonate ($MgCO_3$), from 0.065 to 0.085 part per 1,000.

In these analyses, in some instances, as much as 0.066 part per 1,000 of carbon dioxide (CO_2) was found, supposed to be in excess of the amount combined with the calcium and magnesium.

These analyses and many others that might be cited show that all the acids and bases found in marl are present in the lake waters beneath which it usually occurs.

The occurrence of extensive and thick beds of marl in the bottoms of existing lakes, the presence of the substances composing the marl in the lake waters, and other considerations make it unnecessary to discuss in detail the obvious conclusion that the marl has in some manner been eliminated from the water of lakes and accumulated on their bottoms. Two general explanations in reference to the manner in which calcium carbonate may be precipitated from lake waters have been proposed; one of these refers it to the direct action of organic agencies, and the other to chemical precipitation.

The presence in the marl of the shells of mollusks of the same species as those still living in the lakes is unquestionable evidence that in part the calcium carbonate and also the magnesium salts have been separated from the water by mollusks and deposited in their shells and on their death contributed to the sediment filling the lake basins. The percentage of shells, however, in the marl, as already stated, is

[a] Water-Supply and Irrigation Paper No. 31, U. S. Geol. Survey, 1899. [b] Pages 28–29.

small. At the surface in certain somewhat exceptional instances, where dead shells have been accumulated through the action of waves and currents, they form a conspicuous portion of the deposit, but as a rule they are present to the extent, by estimate, of only 5 to 10 per cent. Fishes, crustaceans, etc., also inhabit the lakes, but the contributions they furnish to the filling of the basins is obviously insignificant. By far the larger portion of the marl in every deposit thus far examined by the writer, or reported by others who have given attention to this matter, certainly owes its accumulation to other causes than the secretions of animals.

The importance of plants, and particularly of certain algæ, in eliminating calcium carbonate, especially from waters not saturated with that salt or with calcium bicarbonate, has in recent years attracted attention, and the applicability of this principle to account for the accumulation of marl deposits like those so common in Michigan has been admirably investigated by Prof. Charles A. Davis,[a] of Alma College.

In general plant life is abundant in the lakes of Michigan, but the marl lakes are conspicuously barren, except in their deeper portions and when marl gives place to muck. In the lakes where white marl forms the bottom the common rush (*Scirpus lacustris*) grows sparingly, and is usually the only conspicuous plant present. A more careful search, however, will show that certain small blue-green algæ (*Zonotrichia*) are present on the bottom, although perhaps largely concealed by calcareous incrustations. In the deeper portions of such lakes, as well as about their shores, other algæ of the family Characeæ, or stoneworts, commonly thrive luxuriantly. As has been shown by Davis, both the Characeæ, especially *Chara fragilis* and the blue-green algæ, are active in causing the precipitation of calcium carbonate.

The stems of chara are frequently, although not always, incrusted with calcium carbonate, which, as stated by Davis, is not a true secretion of the plant, for it is purely external. "The deposit is formed incidentally by chemical precipitation upon the surface of the plant, probably only upon the green parts, and in performance of normal and usual processes of plant organization." The material obtained by drying a number of stems of chara was found, after removing the organic matter, to have the following composition (Davis):

Composition of stems of chara after removing organic matter.

	Per cent.
Calcium carbonate, $CaCO_3$	93.76
Magnesium carbonate, $MgCO_3$	2.93
Silica and undetermined mineral matter	2.40
Iron and aluminum oxides, Fe_2O_3 and Al_2O_3	.89
Total	99.98

[a] A contribution to the natural history of marl: Jour. Geol., Vol. VIII, 1900, pp. 485–497; also a remarkable marl lake: Jour. Geol., Vol. VIII, 1900, pp. 498–503.

The incrustations on the plants are thus shown to be of essentially the same composition as an average sample of marl. More than this, in many instances, particularly near the shores of lakes, the marl contains an abundance of easily recognizable fragments of incrustations which still retain the form of the stems about which they were deposited. To a marked extent in certain instances, incrusted chara stems are drifted ashore by waves and currents, and accumulate in beaches, bars, and spits. As already stated, an examination of the various portions of marl obtained on passing it through sieves showed the presence, especially in the white marl from Lake Wetzell, of a very large percentage of irregular tubular bodies of calcium carbonate. These tubes are without question the external coats of the stems of chara. It is thus evident that chara plays an important part in the formation of marl deposits.

As previously stated, many marl lakes contain islands and shoals, frequently about an acre in surface area, surrounded by water 30 to 40 feet or more in depth, the marl being about 30 feet or more in depth and presenting steep, submerged slopes on all sides. On the borders of the islands referred to, and on the surfaces and bordering slopes of the shoals, over which there is commonly from 2 to 6 feet of water, there is an abundant growth of both chara plants and the blue-green algæ in all of the instances observed by the writer. Under the theory that the deposition of marl is due largely to the influence of algæ, the only explanation of the origin of the islands and shoals referred to is as follows: The bottoms of the lakes, like the surrounding land, are irregular, and on the elevations the algæ found favorable localities for attachment and grew luxuriantly, thus causing the deposition of calcium carbonate, which built up the previously deeply submerged prominences until the surface was nearly reached. The fact that in several instances the isolated shoals referred to are flat-topped elevations with a few feet of water over them seems to have some relation to the action of the ice which forms each winter. It is an interesting fact that the steep borders of these islands and shoals are similar in every way to the precipitous lakeward slopes of the terraces which occur about the borders of so many marl lakes.

In the lakes containing the most abundant deposits of marl, and especially the white variety, it occurs largely in terraces about their borders. On the surfaces of these terraces chara is usually absent or grows sparingly, but on their steep lakeward borders it is commonly abundant. This relation of the chara to the topography of the lake bottoms seems to indicate that the terraces have grown outward by additions to their lakeward borders, owing to the more abundant precipitation of calcium carbonate in such localities.

Blue-green algæ are usually to be found on the surface of the marl terraces, but whether more numerous in such places than elsewhere is not clear, as their presence in other associations is usually masked by the greater abundance of other vegetation. The nodules of calcium carbonate referred to in the description of the physical characteristics of marl (p. 656) when dissolved in weak acids usually leave a gelatinous or filamentous mass of algæ having the general character of *Zonotrichia.* Here, again, it is evident, as has also been pointed out by Davis, that there is an intimate connection between plant life and the deposition of calcium carbonate. As in the case of the incrustations of the chara, those just noticed are superficial and inclose the still living algæ.

In reference to the calcareous nodules so abundant in several lakes, and the larger but less common incrustations on unio and anodon shells, Davis stated that a colony of algæ (*Zonotrichia*) seems to start at some point of attachment or on some object like a shell, and grow outwards rapidly in all directions, each filament independent of all others and all precipitating calcium carbonate tubules. The tubules are strong enough to serve as points of attachment for other plants, and thus add themselves to the little spheroids and entrap particles of solid matter which in turn are held by new growths of the lime-precipitating *Zonotrichia.* Thus a pebble is formed, which, to the casual observer, is not noticeably different from ordinary water-rounded stones.

An important fact in connection with the discussion just considered is that by no means all of the lakes in a region where marl-depositing water bodies are present contain marl. Two lakes frequently occur near each other and perhaps side by side, one of which contains a deep deposit of nearly pure marl, and the other an equally abundant accumulation of muck or peat. Even in the same lake, as already stated, there are frequently abrupt transitions from one of the deposits just mentioned to the other. Where the bottom of a lake is formed of peat, one almost invariably finds a luxuriant growth of both algæ and the water-loving flowering-plants. Calcareous material occurs in much of the peat, but it is masked by the far greater percentage of organic matter present. In lakes in which there is an abundance of the higher forms of vegetation, as well as of algæ, the water is frequently amber colored on account of vegetable matter in solution, and in such instances it may be presumed, although the fact has not been proved, that the vegetable acids present prevent the precipitation of calcium carbonate.

The precise manner in which the algæ cause the precipitation of calcium carbonate has not been determined. In ordinary surface waters calcium while in solution is believed to exist as the bicarbonate, there being free carbon dioxide present. As stated by Davis, the plants favor the precipitation of calcium, both by abstracting the carbon dioxide, thus causing the calcium salt to change to the monocarbonate and be precipitated, and by liberating oxygen, which also possibly leads to the throwing down of the calcium monocarbonate. In water containing a relatively small amount of calcium bicarbonate the liberation of oxygen is believed by Davis to be the more probable method by which precipitation is brought about. The calcium monocarbonate is deposited in minute crystals on the outside of the plants, and by the aggregation of these crystals the incrustations are formed. On the living chara stems examined by the writer under the microscope only a delicate incrustation of crystals of calcium carbonate was found and no deposits approaching in thickness the walls of the tubes so common in the marl were observed. The dead stems of chara, found on the shores of marl lakes, however, are commonly much more thickly incrusted than the living plants. While the presence of incrustations on the stems of chara and on the filamentous blue-green algæ is common, and much of the marl evidently originates in this manner, it does not seem to be definitely proved that this in connection with the shells of mollusks is the only method by which the marl beds have been formed.

The incrustations on the stems of chara are external, as stated, and it seems questionable if, after the first coating is formed, the process of eliminating carbon dioxide, or of freeing oxygen, in the manner just referred to, could go on with sufficient activity to lead to the thickening of the inclosing layer to the extent observed on the dead chara stems. In this connection it may be mentioned that the moulds of chara stems observed in the marl are thicker than the diameters of the tubes they inclose. More than this, if the plants grow where the water is in motion, as has frequently been observed to be the case, their influence in diminishing the amount of carbon dioxide present and of enriching the waters in oxygen, must be, to a great extent, counteracted. These considerations, as well as the scarcity of algæ, especially in the lakes containing extensive deposits of marl, raise the question whether direct chemical precipitation may not be accountable for the crystallization of a portion of the calcium carbonate.

There are, as is well known, two facts which must be kept in mind in determining the mode in which calcium carbonate is thrown down from lake waters; one is that when water is concentrated by evaporation until the point of saturation is reached precipitation will follow; the other is the fact that calcium carbonate, unlike most analogous substances, is more readily soluble in cold than in warm water.[a] To

[a] As stated by Fresenius, pure water when cold will dissolve calcium carbonate in the proportion of one part of the salt to 10,800 parts of water, and 8,875 parts if the water is boiling; but in the presence of free carbon dioxide cold water will dissolve one part in about 1,000, the calcium when in solution is believed to be in the condition of a bicarbonate.

F. H. Storer, in his Dictionary of Solubilities, states that calcium carbonate is soluble in 8,834 parts of boiling water, and in 1,061 parts of cold water; he also says that the calcium carbonate becomes less and less soluble as the temperature is elevated, and at 150° may be regarded as completely insoluble.

these may be added the not well-understood phenomenon that when crystals of calcium carbonate are present in water, they may receive additions even when the water is below the point of saturation.

In attempting to apply these laws in explanation of the origin of marl certain difficulties are met with which call for more investigation than the subject has yet received before decisive conclusions can be reached. No available analysis of the water of the lakes and streams of Michigan shows that calcium carbonate is present in sufficient quantity to produce saturation even when free carbon dioxide is absent, yet special studies in this direction are lacking. Certain conditions observed in the field favor the suggestion that in at least a few marl lakes calcium carbonate may be thrown down during the summer season on account of concentration by evaporation. While the majority of the marl lakes have inflowing and outflowing streams and no considerable concentration of their waters can be expected to occur, there are other lakes which are without surface tributaries except temporary rills during storms, and which have only small outflowing streams or none at all. The level of the water in this class of lakes is controlled by the height of the ground water, or the water-table, in the neighboring hills and gravel plains. That is, the lakes are essentially wells, into which there is an inflow by percolation during the humid portions of the year when the level of the ground water rises, and an outward percolation during the drier portions of the year when the level of the ground water is depressed. Examples of lakes of this class are furnished by a small marl lake about 1 mile east of Oxford in Oakland County, and by two others at a less distance west of the same town; by Silver Lake in the southeastern portion of Genesee County, near Fenton; and by Lake Wetzell in Antrim County. Not all of the lakes of the class just referred to, however, contain marl, as is shown by interesting examples near Baldwin in Lake County, where in close association with several marl lakes having surface outlets, there are two similar basins occupied by lakes that do not overflow, and yet are without marl deposits.

Another hypothesis, suggested by the conditions observed in a large number of marl lakes, is that cool water, containing the normal amount of calcium carbonate present in such instances, enters the basins by percolation and becomes warmed, especially in their shallow marginal portions, and is at the same time concentrated somewhat by evaporation, the precipitation of calcium carbonate being thus favored in two ways. In this process a loss of free carbon dioxide would also occur, this again exerting an influence in the same direction. Under this hypothesis it is reasonable to assume that the most abundant precipitation would take place in the shallow waters about the lake margins and that the peculiar marl terraces present in many of the lakes referred to would be formed. The objections to this hypothesis which may be urged are that both chara and the blue-green algæ are present in all the marl lakes, and their influence in causing the precipitation of calcium carbonate is difficult to eliminate from the discussion. Furthermore, even if the lake waters are found on analysis to be saturated with calcium carbonate, that condition is what would be expected from the fact that the lake basins are lined with marl up to the normal water level, and in some instances, as in the case of Lake Wetzell, to a height of several feet above that level, this calcium carbonate would be taken in solution in case the waters were not saturated with calcium salts from other sources.

According to our present knowledge concerning the origin of marl it appears that the calcium carbonate, which is its principal constituent, is to some extent composed of shells, but more largely is a precipitate from lake water through the action of algæ, although direct chemical precipitation from concentration by evaporation, rise in temperature, and the accompanying escape of free carbon dioxide into the air may occur. A hypothesis worthy of consideration in this connection is that the algæ cause the formation of minute crystals of calcium carbonate on their stems and fronds, and that the presence of these crystals induces further precipitation, in part and most commonly from water that it is not saturated with calcium bicarbonate.

The origin of the magnesium carbonate commonly present in the marl, to the extent of from 1 to 4 per cent, remains to be investigated; but as both the shells of mollusk and the incrustations that form on algæ contain this salt, its presence can seemingly be safely referred to organic agencies. The sulphuric anhydride present may reasonably be accounted for as resulting from the decay of organic matter.

Important studies in reference to the origin of marl by chemical precipitation are now being carried on by Mr. H. E. Brown, chief chemist of the Michigan Portland Cement Company, which, together with the investigation still being continued by Prof. C. A. Davis,[a] give promise of interesting results.

SHALE.

The argillaceous materials thus far utilized in the manufacture of Portland cement in Michigan are shale and clay.[b] The shale is obtained from the Traverse group and the Coldwater formation. In each instance the deposits are of marine origin, as is shown by the fossil shells they contain.

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[a] The instructive results of Professor Davis's studies have been abundantly confirmed by Dr. C. Wesenberg-Lund, who has recently written on the fresh-water lake deposits of Denmark: Meddelelser fra Dansk Geologisk Forening, No. 7, Copenhagen, 1901. Since this report was written "A second contribution to the natural history of marl," by Charles A. Davis, has been published in the Journal of Geology, Vol. VIII, 1900, pp. 491–506.

[b] The most important source of published information in this connection is H. Ries's report on the Clays and shales of Michigan, in Rept. Geol. Survey Michigan, Vol. VIII, Pt. I, 1900. This report contains many chemical analyses, together with tests of the properties of the clays and shales, etc , and should be carefully studied by all who are interested in the utilization of the materials referred to.

SHALES OF THE TRAVERSE GROUP.

The shale of the Traverse group is utilized by the Alpena Portland Cement Company in connection with limestone from the same formation, and is obtained from quarries about 7 miles north of Alpena and near the shore of Lake Huron. The strata are nearly horizontal and consist of alternating layers of fine-grained and uniform bluish-black shale alternating with thin-bedded impure limestone. At the locality where the quarries are located the shale occurs at the surface, being covered only by 2 or 3 feet of peat. The same bed is understood to occur in the low bluff bordering the neighboring portion of Lake Huron. The surface portion of the shale where now exposed is disintegrated to a depth of a few inches, so as to form a stiff blue clay, and both the surface material and the unweathered shale beneath are suitable for cement making. The general composition of the shale is indicated by the following analyses:

Analysis of shale of the Traverse group from near Alpena.[a]

[Analysts, A. N. Clark (A) and H. Ries (B).]

Constituent.	A.	B.
	Per cent.	*Per cent.*
Silica, SiO_2	55.95	58.60
Alumina, Al_2O_3	17.43	17.66
Ferric oxide, Fe_2O_3 (all iron computed as Fe_2O_3)	7.67	7.44
Calcium carbonate, $CaCO_3$	2.14	2.14
Magnesium carbonate, $MgCO_3$	1.55	2.14
Alkalies, as K_2O	2.86	....
Water, organic matter and difference	12.40	11.97
Total	100	100
Ferrous iron, FeO	.50	....

[a] Geol. Survey Michigan, Vol. VIII, Pt. I, p. 46.

Another analysis of shale from the same locality as the above, supplied by the Alpena Portland Cement Company, is as follows:

Analysis of shale of the Traverse group from near Alpena.

[Analyst, S. H. Ludlow.]

Silica, SiO_2	57.96
Alumina, Al_2O_3	20.44
Ferric oxide, Fe_2O_3	3.03
Calcium carbonate, $CaCO_3$	9.12
Calcium oxide, CaO	.28
Magnesium carbonate, $MgCO_3$	5.02
Sulphuric anhydride, SO_3	.72
Alkalies, Na_2O and K_2O	3.40
Total	99.97

The region in the northern portion of the Southern Peninsula, in which the shales of the Traverse group may be expected to outcrop on the border of the adjacent lakes, along the sides of streams, etc., or may be discovered by making small excavations, is indicated on the map (Pl. XLIV).

COLDWATER SHALES.

The Coldwater shales are now being quarried at a locality about 1½ miles east of Union City and utilized by the Peerless Portland Cement Company. At the quarry referred to the shales are well exposed to a depth of from 20 to 35 feet, are thin bedded, horizontal, and contain irregular concretions of ferrous carbonate, some of which are charged with fossil marine shells. The rocks near the surface are much weathered and so completely disintegrated that the evenly bedded bluish shales below pass upward into yellowish mottled clays near the surface. In the manufacture of Portland cement an approximately equal mixture of the weathered and unweathered material is now used. The range in percentage of the several constituents composing the shale is as follows:

Analyses of Coldwater shale from near Union City.

[Analyst, A. Lundteigen.]

	Per cent.
Silica, Al_2O_3	67.89 to 59.20
Iron and aluminum oxides, Fe_2O_3 and Al_2O_3	29.89 to 23.33
Calcium, CaO	1.42 to .00
Magnesium, MgO	2.16 to .26
Sulphuric anhydride, SO_3	Trace to .00
Alkalies, by difference	8.55 to 6.00
Moisture, including water of composition	20.50 to 10.00

The Coldwater shales are also used at the works of the Michigan Portland Cement Company, near Coldwater, and there present about the same characteristics as at Union City. Their range in composition is as follows:

Analyses of Coldwater shale from near Coldwater.

[Analyst, H. E. Brown.]

	Per cent.
Silica, SiO_2	57.26 to 61.25
Alumina, Al_2O_3	18.12 to 21.59
Ferric oxide, Fe_2O_3	6.53 to 8.30
Calcium, CaO	1.25 to 1.50
Magnesium oxide, MgO	1.49 to 2.31
Sulphuric anhydride, SO_3	.65 to 1.34
Carbon dioxide, CO_2	.95 to 1.18
Titanium oxide, TiO_2	.82 to 1.12
Alkalies, Na_2O and K_2O	2.25 to 3.45
Loss on ignition	6.19 to 8.32

The shales of this same formation were formerly used by the Bronson Portland Cement Company, but have since been superseded by surface clays obtained in northern Ohio. The shale formerly used at Bronson is reported to have the following composition:

Analysis of Coldwater shale from near Bronson. [a]

[Analyst, C. J. Wheeler.]

	Per cent.
Silica, SiO_2	62.00
Alumina, Al_2O_3	20.00
Ferric oxide, Fe_2O_3	8.00
Calcium oxide, CaO	.50
Magnesium oxide, MgO	1.00
Sulphuric anhydride, SO_3	.50
Organic matter	8.00
Total	100.00

Other analyses of the shales of this formation occurring near Bronson, Coldwater, and at White Rock, compiled from Ries's report, are as follows:

Analyses of Coldwater shale.

[Analyst, H. Ries.]

Constituent.	Bronson.	Coldwater.	White Rock.
	Per cent.	*Per cent.*	*Per cent.*
Silica, SiO_2	62.10	53.44	58.70
Alumina, Al_2O_3	20.09	24.80	18.31
Ferric oxide, Fe_2O_3	7.81		
Calcium oxide, CaO	.65	.76	
Calcium carbonate, $CaCO_3$			1.80
Magnesium oxide, MgO	.96	.25	
Magnesium carbonate, $MgCO_3$			.98
Sulphuric anhydride, SO_3	.49		
Alkalies, Na_2O and K_2O			3.67
Water and organic matter	7.90	20.75	9.35
Total	100.00	100.00	100.00

The Coldwater shales occur beneath the surficial deposits throughout an extensive area in the Southern Peninsula, as is indicated on Pl. XLIV, but are seldom well exposed at the surface. As noted by Ries,[b] however, extensive outcrops occur along the shore of Lake Huron between White Rock and Forsyth, and are thus favorably situated for shipping by water.

At many localities where suitable surface clays can not be had in connection with extensive marl deposits it may be found practicable to mine the underlying Coldwater shales, as was formerly done near Bronson, for use in cement making.

[a] The plant of the Bronson Portland Cement Company, Bronson, Mich., by H. Lewis: Eng. Rec., Vol. XXXVII, 1898, pp. 470–472; reprinted in The Cement Industry, New York, 1900, pp. 33–44.
[b] Geol. Survey Michigan, Vol. VIII, Pt. I, 1900, p. 44.

ANTRIM SHALES.

In addition to the deposits briefly described above, there are two formations in the Southern Peninsula which contain shales that in certain instances, at least, are worth investigating in connection with the industry here considered. These are the Antrim shales, which occur at the summit of the Devonian system, and the Saginaw formation, which forms the upper portion of the Carboniferous system as developed in Michigan. (See Pl. XLIV.)

The Antrim shales usually contain a high percentage of organic matter and yield petroleum, gas, etc., on distillation. No attempts have yet been made to utilize them for making cement, although their physical properties (except, perhaps, their toughness, which renders them somewhat difficult to quarry or to reduce to a powder) and their chemical composition make them worthy of experiment in that connection. An analysis of probably unweathered Antrim shale, made for the purpose of testing its fuel value, published by Ries,[a] is as follows:

Analysis of Antrim shale.

[Analyst, W. H. Johnson.]

	Per cent.
Volatile matter	17.96
Fixed carbon	6.49
Ash	75.55
Total	100.00

Analysis of the ash.

	Per cent.
Silica, SiO_2	70.54
Alumina, Al_2O_3	15.33
Ferric oxide, Fe_2O_3	5.31
Calcium oxide, CaO	2.38
Magnesium oxide, MgO	.78
Alkalies, etc., by difference	5.56
Total	100.00

As remarked by Ries, the ratio of silica to alumina in this analysis is unusually high, but so far as can be judged this material is worth careful investigation on the part of cement makers.

The Antrim shales are exposed on the shore of Thunder Bay, and also at several localities in Charlevoix County, where they are associated with marl deposits. The availability of these shales in manufacturing Portland cement and the utilization of the organic matter they contain as a by-product seems to be a possibility worthy of consideration.

[a] Geol. Survey Michigan, Vol. VIII, Pt. I, 1900, p. 47.

SAGINAW FORMATION.

The shales of the coal-bearing rocks which underlie an extensive area in the central portion of the Southern Peninsula, and are well developed in the productive coal field of the Saginaw Valley, although frequently containing sand, have in some instances approximately the physical and chemical composition desired in cement making. The fact that these shales are frequently removed in the process of coal mining and that facilities for transportation are available claim for them careful attention as a source of material for use in manufacturing Portland cement.

As stated by Ries,[a] three types of shale in the Saginaw formation may be recognized, between which there are intermediate gradations. These are—

First. A light-gray, sandy, shaly clay, often quite hard, called "fire clay," and not infrequently containing fossil plants. Shale of this character is present beneath a coal seam at the mines of the Standard Mining Company near Saginaw, and has the following composition:

Analysis of shale from Saginaw.

[Analyst, H. Ries.]

	Per cent.
Silica, SiO_2	55.30
Alumina, Al_2O_3	14.20
Ferric oxide, Fe_2O_3	3.62
Calcium carbonate, $CaCO_3$	.30
Magnesium carbonate, $MgCO_3$	2.61
Alkalies, K_2O, Na_2O	2.15
Water and organic matter	21.82
Total	100.00
Fluxes	8.68

This shale is evidently too low in alumina and iron in proportion to the silica present to be used to advantage in the manufacture of Portland cement as now practiced.

Second. A black, fine-grained, brittle shale, with dull luster, sometimes termed "cannel coal." It contains much bituminous matter and would not serve well for the manufacture of clay products (Ries).

Third. A dark, grayish-black, fine-grained, hard, yet brittle shale, which is appreciably plastic when ground and mixed with water. Shale of this type is found in several of the mines near Saginaw and Bay City, and is quarried at Flushing for the manufacture of paving brick. Similar shales are associated with coal seams near Jackson and may be expected to occur throughout the area indicated as being occupied by the Saginaw formation on Pl. XLIV.

[a] Geol. Survey Michigan, Vol. VIII, Pt. I, 1900, pp. 25–38.

The chemical composition of the shales just referred to is indicated by the following analyses:

Analyses of shales of the Saginaw formation.

Constituent.	1.	2.	3.	4.	5.	6.
Silica, SiO_2	54.50	52.45	57.10	61.13	54.93	41.38
Alumina, Al_2O_3	30.75	23.27	20.02	26.90	31.43	27.02
Ferric oxide, Fe_2O_3	3.50	7.93	8.18			
Calcium oxide, CaO	1.05			1.12	.22	.52
Calcium carbonate, $CaCO_3$		1.82	.71			
Magnesium oxide, MgO	1.69			.96	1.58	.90
Magnesium carbonate, $MgCO_3$		1.06	1.47			
Sodium oxide, Na_2O	.80	4.37	2.76	(?)	(?)	(?)
Potassium oxide, K_2O	2.20			(?)	(?)	(?)
Water and organic matter	5.51	9.10	9.76	6.47	7.44	23.11
Total	100.00	100.00	100.00	96.58	95.60	92.93
FeO		1.57	1.47			

1. Fine-grained, black shale from Flushing: Geological Survey of Michigan, Vol. VIII, Pt. I, 1900, p. 30. Analyst, H. Ries.
2 and 3. Shales associated with coal at Bay City, ibid., pp. 35–36. Analyst, A. N. Clark.
4, 5, and 6. Coal mines at Bay City. Analyses furnished by the Hecla Portland Cement and Coal Company. Analysts, Lathbury and Spackman.

As shown by these analyses, the shales of the Saginaw formation as a rule are lower in silica than is deemed desirable for use in making Portland cement, but certain beds have been recommended by experts in that industry. Evidently any layer of shale in the Saginaw formation which can be economically mined, and which is free from sand and other objectionable substances visible to the eye, should be carefully tested and experimented with in connection with the industry under review.

CLAY.

Surface clays deposited during the Pleistocene period of geological history—that is, at a late date, and after the land had about its present relief—are abundant throughout Michigan. These clays were in part left on the surface of the country directly by the glaciers during the last ice invasion of the Glacial epoch, or in some instances by streams flowing from the glaciers; in part were laid down in small lakes and in the waters of the Great Lakes when more widely expanded in certain directions than at present, and in part were spread out in the flood plains of streams. These three varieties may be termed, to adopt the classification used by Ries,[a] drift clays, lake clays, and river silts.

The drift clays are invariably calcareous and usually contain sand, stones, and bowlders, and show much variation in composition. They

[a] Geol. Survey Michigan, Vol. VIII, Pt. I, 1900, pp. 48–62.

are the most abundant of the surface clays and frequently form the hills and uplands. In numerous instances they are used in the manufacture of bricks, tiles, etc., although in general not well adapted for this purpose. On account of their usual sandy and stony character and irregularities in composition, they are seldom worth investigating in reference to the making of Portland cement. In some exceptional instances, however, the glacial clays are essentially free from gravel and sand, but contain at intervals irregular nodules of calcium carbonate, which, if the material were used in making cement, would necessitate great care in mixing and grinding to form a slurry.

The chemical composition of typical examples of drift clay, when free from gravel and sand, is here presented:

Analyses of drift clays.

Constituent.	1.	2.	3.	4.	5.	6.
Silica, SiO_2	54.94	45.27	46.22	40.15	41.86	52.26
Alumina, Al_2O_3	12.14	15.33	15.02	11.25	10.70	22.95
Ferric oxide, Fe_2O_3	4.88	6.65	5.49	4.88	5.02	8.15
Calcium oxide, CaO	9.13	11.32	10.85	....	14.33	4.48
Calcium carbonate, $CaCO_3$	....	....	....	21.43	....	....
Magnesium oxide, MgO	3.65	4.08	4.52	....	2.81	1.32
Magnesium carbonate, $MgCO_3$	....	....	....	8.93	....	....
Sulphuric anhydride, SO_3	None.	Trace.	Trace.	....	....	....
Carbon dioxide, CO_2	....	....	....	....	14.56	....
Sodium oxide, Na_2O	?	....	....	2.06	2.80	....
Potassium oxide, K_2O	?	....	....			....
Water and organic matter[a]	12.44	13.75	15.31	11.30	8.00	10.56
Sand	....	3.44	1.20	....	....	....
Total	97.16	98.84	98.61	....	100.08	99.72

[a] Loss on ignition.

1. Brickyard near Pinckney, Livingston County. Furnished by Standard Portland Cement Company. Analysis by E. D. Campbell.
2. From 3 miles north of Jackson. Furnished by Standard Portland Cement Company. Analysis by E. D. Campbell.
3. From near Stockbridge, Ingham County. Analysis by E. D. Campbell.
4. From Ionia, Ionia County. Analysis by A. N. Clark: Geol. Survey Michigan, Vol. VIII, Pt. I, 1900, pp. 51–53.
5. From near Jackson, Jackson County. Analysis by H. Ries: Geol. Survey Michigan, Vol. VIII, Pt. I, 1900, pp. 56–59.
6. From Springport Township, Jackson County. Analysis by Mariner and Hoskins: Geol. Survey Michigan, Vol. VIII, Pt. I, 1900, p. 60.

The lake clays are well represented, especially about the border of the southern peninsula, as between Detroit and Ypsilanti, about Port Huron, South Haven, widely over the Saginaw Valley, and in numerous local basins throughout the State. In the Upper Peninsula extensive deposits of exceedingly fine-grained, laminated pinkish clay, deposited from the water of Lake Superior when more widely expanded than now, occur in abundance at Sault Ste. Marie, and have a wide distribution westward, as at Marquette, Escanaba, etc. The chemical composition of this extensive deposit is indicated by analysis 6 in the following table, which shows that it is suitable for cement making.

The lake clays here referred to are characteristically fine grained, many times almost entirely free from grit, highly plastic, and uniform in composition. As shown by numerous chemical analyses, however, they are what are termed "lean clays;" that is, not high in alumina and ferric oxide in proportion to the silica present, and not, as a rule, considered favorable for cement making. These properties and the usual presence of calcium, together with the frequent occurrence of sulphuric anhydride, are shown by the following analyses:

Analyses of lacustral clays.

Constituent.	1.	2.	3.	4.	5.	6.
Sand	....	....	1.51	....	?	....
Silica, SiO_2	49.75	49.34	66.49	47.75	46.40	61.62
Alumina, Al_2O_3	13.06	14.50	9.87	17.60	16.4	17.20
Ferric oxide, Fe_2O_3	5.31	5.37	4.87	9.13		5.99
Calcium oxide, CaO	10.86	9.75	4.72	....	....	5.62
Calcium carbonate, $CaCO_3$	....	....	....	2.60	25.36	....
Magnesium oxide, MgO	4.28	4.77	1.22	....	....	2.82
Magnesium carbonate, $MgCO_3$	....	....	....	.70	4.30	....
Sulphuric anhydride, SO_3	....	.13	.62	....	....	.46
Sodium oxide, Na_2O	?	?	?	2.21	....	....
Potassium oxide, K_2O	?	?	?		....	....
Water, H_2O	[a]15.07	[a]15.55	[a]9.36	22.01	7.00	[a]5.34
Total	99.13	99.25	98.66	100.00	99.46	99.00

[a] Loss on ignition.

1. From near Chelsea, Washtenaw County. Analysis by E. D. Campbell.
2. From near Fenton, Genesee County. Analysis by E. D. Campbell.
3. From near Farmington, Oakland County. Analysis by E. D. Campbell.
4. From near Saginaw. Analysis by H. Reis: Geol. Survey Michigan, Vol. VIII, Pt. I, 1900, p. 55.
5. From Wyandotte: used in cement making by the Michigan Alkali Company. Analysis by O. Button.
6. Sault Ste. Marie. Analysis by E. D. Campbell.

The river silts occur on the border of many streams, sometimes in terraces a few feet above their surfaces. Although in many instances available for brick and tile making, they are usually too sandy to be employed in manufacturing Portland cement without being ground, so as to have the requisite degree of fineness—that is, so as to pass through a sieve with 150 to 200 meshes to the linear inch. No analyses of typical examples of the river silts are available, but as the deposits are derived mainly from the drift clays, they no doubt have the same composition, lacking, perhaps, some of the calcium carbonate and alkaline salts.

In general it may be said that the surface clays of the Southern Peninsula are not favorable for use in making Portland cement, although some of the stony clays, if crushed sufficiently fine, may be employed for that purpose. Reference is not here made to the decomposed outcrop of the shales described in the preceding section, which might perhaps be taken for surface clays, some of which have been used with favorable results. In reference to the surface clays of the Northern Peninsula little accurate information is available, excepting the analysis of a representative sample of the extensive deposit of pink clay near Sault Ste. Marie, given above.

In a summary of the results of Ries's investigations of the shales and clays of Michigan, already referred to several times, A. N. Clark remarks as follows:[a]

> For use in the manufacture of Portland cement the shales of the Coldwater series are best adapted. The shales of the Michigan series are also good if not too high in soluble salts. Some of the Coal Measure shales, which are often too gritty, and some of the clays derived from the weathering of these shales or the Devonian black shales, may be suitable. Surface deposits of clay of any size are, almost without exception, either too calcareous and irregular in composition or too gritty to be desirable.

The difficulty of obtaining a suitable clay to use in connection with the marl deposits of the southern portion of the Southern Peninsula has led several of the Portland cement companies now in operation in that region to employ clay brought from Ohio. The most of this material comes from Milbury and Bryan and is a lacustral clay, deposited from the waters of the Erie Basin (glacial Lake Warren) when more widely expanded to the southwestward than now. Its composition is as follows:

Analyses of Ohio clays.

Constituent.	1.	2.
Silica, SiO_2	[1]62.55	61.03
Alumina, Al_2O_3	17.46	18.10
Ferric oxide, Fe_2O_3	5.08	6.65
Calcium oxide, CaO	2.30	1.29
Magnesium oxide, MgO	1.67	.53
Sulphuric anhydride, SO_3	Trace.	1.05
Loss on ignition	5.55	9.21
Total	98.37	99.86

[1] With the silica is included 3.76 per cent of fine sand.

1. Milbury. Analysis by E. D. Campbell.
2. Bryan. Analysis by John G. Dean and N. S. Potter, jr.

[a] Geol. Survey Michigan, Vol. VIII, Pt. I, 1900, p. 64.

GYPSUM.

It is commonly found desirable to add from 1 to 2 per cent of gypsum to Portland cement clinker before grinding, in order to regulate the time of setting of the cement when it is mixed with water. The influence of the gypsum, for reasons not well understood, is to delay the time when the cement begins to harden, or, as the expression is, "to acquire its initial set." Michigan possesses extensive deposits of gypsum, particularly at Grand Rapids; and it is from that place that most if not all of it used by the Portland cement factories in this State derive their supply.

The price of ground gypsum, or plaster, as it is termed when used as a fertilizer, at Grand Rapids during 1900 was about $1 a ton. The grinding of the gypsum before adding it to the clinker is unnecessary, and at certain of the factories selected pieces of the crystalline rock are used.

FUEL.

In calcining the material from which Portland cement is made, at the factories now in operation in Michigan, pulverized bituminous coal is used in the rotary kilns and crushed coke in the dome kilns.

For heating the rotary kilns, bituminous coal, after being thoroughly dried, is ground to a fine dust of which at least 98 per cent will pass through a sieve having 100 meshes to the linear inch. This dust is driven into the lower end of the kiln by means of an air blast, and on ignition produces a jet of flame usually some 15 feet long. In most instances the air blast is cold, but in one or two factories it is heated to about 150° F. At the plant of the Michigan Alkali Company, at Wyandotte, the clinker is cooled by means of an air blast, which passes on into the rotaries, after receiving the proper amount of coal dust, with a temperature of about 1,000° F.; by this means the daily output of each kiln is said to have been increased to the extent of 20 to 25 per cent above what it was when a cold-air blast was used.

In the preparation of the coal dust used coal slack or the fine fragments resulting from coal mining are generally employed. The cost of this material is reported to be about $1.50 a ton at the cement factories. At the works of the Bronson Portland Cement Company, however, ordinary steam coal is used instead of slack, the reason stated being that slack is apt to contain scrap iron, which endangers the grinding machines.

In the cement factories of the southern portion of Michigan the coal used both for burning clinker and for generating steam is brought from Ohio and Pennsylvania. The Alpena Portland Cement Company uses both Ohio and Saginaw Valley coal.

For the burning of cement clinker in rotaries a coal rich in volatile matter, low in ash, and free from sulphur is desired. The composition of the coal now being used in Michigan for this purpose is indicated by the following analyses:

Analyses of coal used in burning clinker.

Constituent.	1.	2.	3.	4.
Fixed carbon	56.15	56.33	55.82	51.69
Volatile matter	35.41	35.26	39.37	39.52
Ash	6.36	7.06	3.81	6.13
Moisture	2.08	1.35	1.00	1.40
Sulphur	1.30	1.34	.42	1.46

1. West Virginia coal used by Michigan Portland Cement Company at Coldwater. Analysis by H. E. Brown.
2. West Virginia coal used by Michigan Portland Cement Company at Quincy. Analysis by H. E. Brown.
3. Pennsylvania coal used by Omega Portland Cement Company.
4. West Virginia coal used by Peninsular Portland Cement Company. Analysis by J. G. Dean.

The analysis of coal used by the Omega Portland Cement Company was furnished by Mr. C. F. Wade, secretary and treasurer of the company, who says:

The coal we are using is furnished by the Pittsburg Coal Company, and is from their Harrison and Ocean mines; it is taken from drift shafts, and contains very little moisture. We aim to grind at least 98 per cent fine on a 100-mesh sieve, but at least 60 per cent will pass through a 200-mesh sieve. We use a Cummer drier.

The coal mined in the Saginaw Valley is finding favor with cement manufacturers, but so far as can be judged from inspection of the coal as it comes from the mines, and from such analyses as are available, it is apt to be high in moisture and sulphur, iron pyrites being usually conspicuous. An analysis of Saginaw Valley coal, made by the Solvay Process Company, of Syracuse, N. Y., is reported as follows:[a]

Analysis of Saginaw Valley coal.

	Per cent.
Moisture	7.60
Volatile carbonaceous matter	37.895
Fixed carbon	50.73
Ash	3.77
Total	100.00
Sulphur	.99

[a] The Michigan Miner, Vol. I, No. 8, 1899, p. 20.

The following analyses probably represent fairly the general character of the coals of Michigan, although more favorable results have been reported:

Analyses of Michigan coal.[a]

Constituent.	1.	2.	3.	4.	5.	6.
Moisture	10.15	10.67	7.79	7.58	5.93	7.00
Volatile matter	33.14	33.59	34.74	35.70	46.59	39.10
Fixed carbon	53.95	53.80	52.58	52.99	44.64	46.40
Ash	2.76	1.94	4.89	3.76	2.84	7.50
Total	100.00	100.00	100.00	100.00	100.00	100.00
Total sulphur	1.10	1.01	1.1	1.50	3.07	3.42

1. Section of main coal, Pere Marquette mine, shaft No. 1 (92 inches). Analysis by H. I. Williams.
2. Section of main coal, Standard mine (44 inches). Analysis by H. I. Williams.
3. Section of main coal, J. H. Somers mine (35 inches). Analysis by H. I. Williams.
4. Section of main coal, Owosso Coal Company. Analysis by H. I. Williams.
5. Selected lump of New Hope coal, Jackson. Analysis by H. I. Williams.
6. Selected lump Grand Ledge coal. Analysis by A. N. Clark.

The following average analysis of coal from the Robert Gage mine at St. Charles, Mich., has been furnished by the Robert Gage Coal Company, of Bay City:

Analysis of St. Charles coal.

[Analyst, Frank S. Kedzie.]

	Per cent.
Moisture	2.37
Volatile carbon	35.67
Fixed carbon	58.47
Ash	2.46
Sulphur	1.03
Total	100.00

These analyses of Michigan coal indicate that in certain instances it will compete favorably with the best of the Ohio and Pennsylvania coals, and should receive careful attention from cement makers.

At the cement factories at Bronson and Coldwater crude petroleum from Ohio was formerly used to burn the clinker, being forced into the rotaries by means of an air blast, but this method has been abandoned in favor of coal dust.

Methods are being considered by certain of the Portland cement companies now maturing plans for their factories for the utilization of peat for burning clinker. The proposition is to dry and pulverize the peat and introduce it into rotary kilns by means of an air blast, in the

[a] A. C. Lane in The Michigan Miner (published at Saginaw, Mich.), Vol. I, No. 10, 1899, p. 10. Much additional information respecting Michigan coals, particularly as to their mode of occurrence, thicknesses of the seams, heat-producing properties, etc., may be found in the series of articles here referred to.

same manner that coal dust is now used. This method has not been put to a practical test, and it seems doubtful if the peat can be dried and prepared for grinding as cheaply as coal slack can be delivered at the factories. Peat is commonly associated with marl in Michigan, and in many instances will have to be removed from above the marl before the latter can be utilized, and it is highly desirable that some use should be made of it. The peat, however, is in the majority of instances highly charged with water, and perhaps more properly should be termed muck. Seldom if ever does it form a compact turf which can be cut into blocks and dried, as in many of the Irish bogs. No analyses of Michigan peat made for the purpose of discovering its fitness for fuel are available, but the soils of certain swamps which have been drained and are now cultivated especially for the growing of celery have been analyzed. These soils are really peat deposits, and in some instances overlie marl beds. Their composition indicates what may be expected when the peat swamps are sampled for the purpose of ascertaining their utility as fuel.

Analyses of Michigan celery soils.[a]

[Analyst, R. C. Kedzie.]

Constituent.	1.	2.	3.
Sand and silicates	19.16	24.09	24.56
Alumina, Al_2O_3	1.40	1.71	2.21
Ferric oxide, Fe_2O_3	3.94	3.52	1.30
Lime, CaO	6.09	5.02	4.18
Magnesia, MgO	.81	.62	.75
Potash, K_2O	.34	.20	.42
Soda, Na_2O	.38	.33	.40
Sulphuric anhydride, SO_3	1.31	1.04	.67
Phosphoric acid, P_2O_5	.88	.69	.46
Carbonic acid, CO_3	1.95	1.05	1.10
Organic matter	63.76	61.73	63.75
Total	100.12	100.00	99.80
Water, H_2O	6.51	10.85	7.31

1. From celery farm near Kalamazoo.
2. From celery farm near Grand Rapids.
3. From celery farm near Newberry, Luce County.

These analyses indicate that Michigan peat contains from 30 to 35 per cent of ash, which would exclude it from the list of desirable fuels for burning cement.

In the dome kilns in use at Union City, as already stated, crushed coke is utilized for fuel.

[a] Michigan Agricultural Experiment Station, State Agricultural College, Bulletin 99, 1893, p. 12.

FACTORIES, PROCESS, ETC.

During the year 1900 there were five Portland cement factories in operation in Michigan, and several others in various stages of construction. The status of the industry in May, 1901, together with the output of cement, its value, etc., during the year 1900, is presented in the table on pages 684–685. In addition to the facts given in the table the following notes are deemed worth recording. For the sake of economizing space only the ways in which certain factories differ from the prevailing type are for the most part here referred to.

With the exception of the works of the Peerless Portland Cement Company, at Union City, all of the Portland cement plants now in operation in Michigan are using rotary kilns. Rotaries will also be used in all of the plants now in process of construction, and so far as can be learned in all of those which are projected. The rotary kilns are thus the prevailing type, and it is stated on good authority that it is likely the dome kilns in use at Union City will soon be replaced by the more modern type. The general processes of manufacture employed in the two styles of kilns have been briefly described on previous pages of this paper, and it only remains to note some of the more important peculiarities of certain of the plants using rotaries.

All of the factories that are provided with rotaries, and all that are being built or the designs for which are under consideration, so far as can be learned, will use the wet process, with the exception of the factory to be erected by the Lupton Portland Cement Company, where what is known as the dry process will be employed. The difference between these two methods, it will be remembered, is, in general, that in the wet process the lime and clay ingredients are ground together with about 60 per cent of water, the slurry thus formed is conveyed to the rotaries and as it passes through them is dried and calcined—that is, the drying and burning are parts of one continuous process; in the dry process the slurry is dried before passing to the rotaries, but is moistened on entering them to prevent its being blown away as dust before it is made to cohere on account of the heat present; the drying and burning are thus two separate processes.

The rotaries in which the wet process is used are 60 feet long, and those into which the slurry is dried before entering are 40 feet in length, the diameter of the kilns in each case being the same, namely, 6 to 7 feet. Which of these two processes will ultimately be found the more economical remains to be determined.

At the factory of the Alpena Portland Cement Company, as already stated, limestone and shale are used, and several operations of the process of manufacture are different from those practiced when marl and shale or clay are employed. The limestone and shale as they come from the quarries are mixed in approximately the correct proportions and passed through a crushing machine. After receiving about 40 per cent of water the mixture is ground in ball and tube mills and forms a slurry which, after being corrected, if necessary, in chemical composition, is pumped to the rotaries. The slurry contains some 20 per cent less water than is usually present in the similar mixture in which marl is used, and rotaries 40 feet long are employed.

At the cement works of the Michigan Alkali Company, at Wyandotte, as already stated, precipitated calcium carbonate, a by-product from the manufacture of caustic soda, is used instead of limestone or marl. This material is exceedingly fine, but the clay used in connection with it contains a considerable percentage of sand, and the slurry requires careful grinding. As the process is now conducted, the slurry containing 40 per cent of water is ground until 94 per cent will pass through a sieve having 200 meshes to the linear inch. On account of the comparatively small amount of water in the slurry, 40-feet rotaries are employed. This factory, as already stated, is the only one now in operation in Michigan which uses a hot blast to drive the coal dust into the kilns.

In the majority of the factories now in operation the clay or shale used is dried and coarsely ground before being mixed with marl, with the addition of water, to form slurry. The advantage of this method is that it facilitates the work of the chemist in obtaining the desired mixture.

The power used to move the machinery in the Michigan cement plants is, except at one factory, steam. At Newaygo water power is employed. In the majority of the factories in which rotaries are used the power is distributed by means of electricity.

For the grinding of clinker certain factories use ball or tube mills, consisting of large steel cylinders revolved in a horizontal position, and about half filled with either steel balls, or chert pebbles; the clinker is placed in the cylinder together with the balls or pebbles and is finely ground by attrition. In other instances Griffin mills are employed, each of which consists essentially of an inclosed mortar in which a heavy pestle is made to revolve.[a]

THE FINISHED PRODUCT.

Portland cement as it comes from the grinding machines is a dark gray powder, of which from 92 to 99 or more per cent should pass through a sieve having 100 meshes to the linear inch. Tests of commercial lots of Michigan cement, made for the Michigan Central Railroad Company, show that, as a rule, 97 to over 98 per cent will pass a 100-mesh sieve, and 80 per cent or more will go through a 200-mesh sieve.

[a] Much of value concerning the methods of manufacturing Portland cement, plans of factories, etc., at Bronson and Coldwater, by H. Lewis, may be found in "The Cement Industry," published by the Engineering Record, New York, 1900.

The composition of various brands of Michigan Portland cement is shown by the following analyses:

Analyses of Michigan Portland cement.

Company.	SiO_2.	Al_2O_3.	Fe_2O_3.	CaO.	$CaSO_4$.	SO_3.	MgO.	Na_2O and K_2O.	TiO_2.	Loss on ignition.	Analyst.	Remarks.
Alpena Portland Cement Co.	20.26	8.62	2.71	63.22	....	0.76	2.34	1.34	....	0.75	W.H.Simmons	Pure clinker.
Bronson Portland Cement Co.	22.52	6.69	3.54	63.13	1.67	....	.69	1.08	....	.59	.....do........	Gypsum added.
Great Northern Portland Cement Co.	24.01	5.51	2.38	63.91	....	....	3.40	....	....	....	Booth, Garrett, and Blair.	From prospectus of the company.
Michigan Alkali Co. (Wyandotte).	24.00	7.50	2.40	62.00	1.50	....	2.50	....	....	....	O. Button.....	With gyspum added.
Michigan Portland Cement Co. (Wolverine brand).	21.02	7.24	3.83	63.95	....	1.50	1.05	.98	0.27	.73	H. E. Brown..	About 2 per cent of gypsum added.
Michigan Portland Cement Co. (Eclipse brand).	22.284	7.52	3.141	62.464	....	1.34	2.34	.994	....	....	.....do........	Do.
Omega Portland Cement Co.	24.24	7.26	2.54	64.96	....	.41	2.26	....	....	.33	(Not stated)..	From prospectus of the company.
Peerless Portland Cement Co.	20.65	11.08		65.40	....	.37	1.95	....	....	....	A. Lundteingen.	Pure clinker.
Peninsular Portland Cement Co.	22.56	10.96		62.72	....	1.50	2.20	....	....	....	N.S. Potter, jr.	About 3 per cent of gypsum added.

Various laboratory tests are made of cement by which to judge of its fitness for use. Of these one which is considered important is to make a paste by mixing the cement with water, and from this to form thin pats on glass. The time required for these pats to begin to harden, or acquire an initial set, and the time required for final hardening may thus be obtained. Pats of this nature when placed in boiling water for twenty-four hours serve to suggest what changes will take place in cement with age. Many tests of the nature just indicated have been made by various disinterested parties, Michigan cement having been used, and as good results were obtained as when samples of the best of other American or foreign brands were employed. It is impracticable to record the results of the tests referred to, and they are therefore omitted.

The tests of the strength of cement by breaking briquettes are easy to compare, and for this purpose a series of tests of Michigan cements, made at the office of the Michigan Central Railroad, from samples of commercial lots, are here presented, through the kindness of Mr. Benjamin Douglas, engineer in charge of bridge construction. Each test is the average record from four briquettes.

Tensile strength of Michigan Portland cements, from tests by Michigan Central Railroad.

Brand.	Proportions by weight.		Per cent of water to weight of cement and sand.	Tensile strength in pounds per square inch.				
	Cement.	Sand.		7 days.	28 days.	3 months.	6 months.	1 year.
Bronson[a]	1	0	22	497	519	632	....	......
Do	1	3	12	88	178	197	....	......
Omega	1	0	25	325	546	650	....	......
Do	1	3	12	75	146	251	....	......
Do	1	0	25	398	536	651	....	......
Do	1	3	12	74	133	[b]258	....	......
Do	1	0	23	731	698	733	....	......
Do	1	3	10	222	287	348	....	......
Do	1	0	23	665	742	....	....	......
Do	1	3	10	140	229	....	....	......
Peerless	1	0	24	628	692	....	....	......
Do	1	0	24	588	689	....	....	......
Do	1	0	24	611	712	....	....	......
Do	1	0	25	560	635	....	....	......
Do	1	0	25	487	677	....	....	......
Do	1	0	25	487	677	....	....	......
Do	1	3	12	126	237	302	....	......
Do	1	0	25	455	669	706	....	......
Do	1	3	12	143	174	249	350	......
Do	1	0	27	345	471	474	525	......
Do	1	0	30	344	354	480	453	......
Wolverine	1	0	25	419	554	619	....	......
Do	1	3	10	118	196	280	....	......
Do	1	0	25	724	709	755	....	......
Do	1	3	10	185	303	304	....	......
Wyandotte	1	3	10	207	261	271	348	......
Do	1	0	22	492	474	551	....	......
Do	1	0	22	859	982	989	....	......
Do	1	0	22	473	590	675	....	......
Do	1	0	22	443	611	607	....	......
Do	1	3	10	99	190	254	333	350
Do	1	3	9	169	350	361	354	345
Do	1	3	12	137	243	336	....	......

[a] Only one set of tests available. [b] Average of 3 samples.

The following results of tests of the tensile strength of Michigan Portland cements have been furnished by the companies indicated. As in the previous table, the figures denote the breaking strength of briquettes 1 square inch in area of cross section.

Tensile strength of Michigan Portland cements, from tests made by cement companies.

Company.	Authority.	Character of briquette.[a]	7 days.	28 days.
Bronson Portland Cement Co	F. H. Hutton	Neat	600	700
Do	do	Sand	200	275
Great Northern[b]	Booth, Garrett, and Blair.	Neat	641	950
Do	do	Sand	266	469
Michigan Portland Cement Co. (Wolverine brand).	H. E. Brown	Neat	745	926
Do	do	Sand	364	488
Michigan Portland Cement Co. (Eclipse brand).	do	Neat	701	812
Do	do	Sand	308	471
Omega Portland Cement Co	C. F. Wade	Neat	655	835
Do	do	Sand	339	429
Peerless Portland Cement Co	W. M. Hatch	Neat	563	750

[a] The practice in making these tests is not uniform. Variation in the percentage of water used and method of molding the briquettes may cause a difference of as much as 300 pounds in the tensile strength of the briquettes. A fair comparison of different cements is not possible without a knowledge of the conditions under which the different tests were made.

[b] Sample of cement made in laboratory. From prospectus of the Great Northern Portland Cement Company.

The records presented in the two tables just given may be considered as representing the average of Michigan Portland cement and compare favorably with such published results of tests of other cements, including foreign brands, as are available. The special quality of Portland cement, namely, its slow increase in strength with age, is well shown by the results recorded above.

The final test of all cements is, of course, their soundness and strength after many years of service, and in this connection no definite record can be made, except in the case of the Eagle Portland cement, referred to early in this paper. The cements made in Michigan since 1897 have been widely used, and in a great variety of ways, and in most instances have proved to be satisfactory. One of the common uses to which they have been applied, and the one affording perhaps the most severe test of their quality, is for the laying of walks. The winter climate of Michigan is severe, and the changes of temperature, especially in spring and fall, are abrupt and of wide range, but in the opinion of the writer it can be truthfully said that walks made of Michigan cements have withstood these severe conditions as well as those laid with other cements, including the best German Portland that can be had in this country. Although many cement sidewalks in the cities and villages of Michigan, made of many different brands of Portland cement, have been more or less complete failures, this is due, as is obvious in most of the instances that have come under the writer's notice, to poor work-

BRANDS OF MICHIGAN PORTLAND CEMENT.

manship on the part of contractors, and should not be charged to the cement employed.

The trade marks of the Michigan Portland cement companies now in operation are shown on the accompanying illustration (Pl. XLVI).

GROWTH OF THE PORTLAND CEMENT INDUSTRY.

The recent remarkable development of the Portland cement industry in Michigan is shown on the table on pages 684–685. The first of the factories now in operation was completed in 1897, when the Bronson and Peerless Portland cement companies began operations, and in May, 1901, ten factories were producing cement and six others were in process of construction. The factories now running are provided with 19 dome kilns (at Union City) and 66 rotary kilns, but all of the rotaries are not yet in actual operation. The capacity of the ten plants now built is about 8,000 barrels a day; or, reckoning 300 days to a year, 2,400,000 barrels of cement per annum. The capital stock of all the Michigan Portland cement companies now organized is about $25,000,000, and their estimated capacity approximately 8,600,000 barrels of cement per year.

The total consumption of Portland cement in the United States during the year 1900 was about 10,728,764 barrels, while the amount manufactured was 8,482,020 barrels. The average rate of increase of production during the preceding ten years was approximately 40 per cent a year. It thus appears that Michigan is preparing to supply a demand which does not exist, and as there is similar activity in this same direction in several other States, it is evident that the industry is in a speculative stage. There is an abundance of raw material in Michigan suitable for the making of cement, however, and a confident and seemingly well-sustained belief that the demand for cement will continue to increase probably at an accelerated ratio over that of the past ten years, so that a permanent and normal growth of the industry in the State may reasonably be expected after its present speculative phase has subsided. In the opinion of persons competent to judge, it is evident that many of the Michigan Portland cement companies which have sprung into existence during the past few years are overcapitalized, and that some of them will be failures as business enterprises on their present basis.

One of the most pleasing conditions observed by the writer during his visits to the several Portland cement factories now in operation or being built in Michigan was the manifest ready adaptability of their managers to new conditions, their readiness to adopt new and improved methods, their skill in modifying or reconstructing familiar types of machinery, and their ability to originate and apply new ideas. This healthful condition of the industry, as well as the abundance of raw materials, facilities foı transportation, excellence of the finished product, increasing demand, etc., insures its permanence and ultimate success.

Summary of the Portland cement industry in Michigan.

[May, 1901.]

Name.	Location of factory.	Incorporated.	Capital stock.	Style and number of kilns.	Material.	Fuel for burning clinker.	Men employed.	Chemists.	Production during 1900.	Value of product for 1900.[a]	Total production to Jan. 1, 1901.	Remarks.
									Barrels.	*Dollars.*	*Barrels.*	
Alpena Portland Cement Co.	Alpena	Aug. 8, 1899	$300,000	Rotaries, 6	Limestone and shale.	Coal dust	90	2				Factory built in 1900–1901. Began making cement in April, 1901.
Bronson Portland Cement Co.	Bronson	Mar. 3, 1897	500,000	Rotaries, 7	Marl and clay	do	50 to 60	2	168,000	278,000	500,000	Factory built in 1897.
Clare Portland Cement Co.	Clare	May 8, 1901[b]	1,000,000	Rotaries	do							Construction not begun.
Detroit Portland Cement Co.	Fenton	Mar. 7, 1900	1,000,000	do	do	Coal dust						Factory being built.
Eagle Portland Cement Co.	Kalamazoo			Vertical, 4	do	Coke					300,000	First 2 kilns built in 1872; abandoned in 1882.
Egyptian Portland Cement Co.	Fenton	June 29, 1900	1,050,000	Rotaries	do	Coal dust or peat.						Factory being built.
Elk Rapids Portland Cement Co.	Elk Rapids	Mar. 8, 1900	400,000	Rotaries, 5	Marl, clay, and shale.	Coal dust	65	2				Completed in February, 1901.
Farwell Portland Cement Co.	Farwell	May 29, 1901	350,000									Construction not begun.
German Portland Cement Co.	White Pigeon	Mar. 20, 1901	320,000	Rotaries, 5	Marl and clay	Coal dust						Factory being built.
Great Northern Portland Cement Co.	Baldwin	Jan. 20, 1900[b]	5,000,000	Rotaries, 72	do	do						Do.
Hecla Portland Cement and Coal Co.	Bay City	(W. Va.)	5,000,000	Rotaries	do							Construction not begun.
Lupton Portland Cement Co.	Lupton	Jan., 1901[b]	1,250,000	Rotaries, 24	do	Coal dust						Construction begun in April, 1901.
Michigan Alkali Co. (Wyandotte).	Wyandotte			Rotaries, 3	Precipitated $CaCO_3$ and clay.	do	38	1	47,000	77,550	47,000	Factory built in 1899.

[a] The average selling price at factories during the year 1900 was about $1.65 per barrel.

[b] Incorporated under the laws of New Jersey.

Summary of the Portland cement industry in Michigan—Continued.

[May, 1901.]

Name.	Location of factory.	Incorporated.	Capital stock.	Style and number of kinds.	Material.	Fuel for burning clinker.	Men employed.	Chemists.	Production during 1900.	Value of product for 1900.	Total production to Jan. 1, 1901.	Remarks.
									Barrels.	*Dollars.*	*Barrels.*	
Michigan Portland Cement Co.	Coldwater	June 6, 1898	2,500,000	Rotaries, 14	Marl and shale.	do	165 to 175	2	150,000	247,500	203,000	Factory completed in 1898.
Do	Quincy			do	Marl and clay.	do	100 to 175	2	56,434	93,016	56,434	Factory completed in 1900.
Newaygo Portland Cement Co.	Newaygo	May 24, 1899	2,000,000	Rotaries, 6	do	do	100					Factory built in 1900 and 1901.
Omega Portland Cement Co.	Mosherville	May 9, 1899	300,000	Rotaries, 5	do	do	60 to 65	2	54,500	89,925	54,500	Factory completed in 1900.
Peerless Portland Cement Co.	Union City	Aug. 23, 1897	250,000	Vertical, 19	Marl and shale.	Coke	100	2	125,000	206,750	250,000	Factory completed in 1897.
Peninsular Portland Cement Co.	Cement City	June 24, 1899	875,000	Rotaries, 6	Marl and clay.	Coal dust	65	2				Factory completed in 1901.
Pyramid Portland Cement Co.	West Jackson	Jan. 17, 1901	525,000	Rotaries, 8	do	do						Construction not begun.
Standard Portland Cement Co.	Lakeland	Nov. 15, 1900	1,000,000	do	do	do						Do.
Three Rivers Portland Cement Co.	Three Rivers	Aug. 10, 1900	20,000									Do.
Twentieth Century Portland Cement Co.	Fenton	Feb. 2, 1901	750,000	Rotaries, 8	Marl and clay.	Peat						Do.
Zenith Portland Cement Co.	Grass Lake	July 17, 1900	700,000	do	do	Coal dust						Factory being built.
Total							823 to 938	19	600,934	992,741	1,410,000	

CHALK OF SOUTHWESTERN ARKANSAS

With Notes on its Adaptability to the Manufacture of Hydraulic Cements

BY

JOSEPH A. TAFF

CONTENTS.

ILLUSTRATIONS.

THE CHALK OF SOUTHWESTERN ARKANSAS, WITH NOTES ON ITS ADAPTABILITY TO THE MANUFACTURE OF HYDRAULIC CEMENTS.

By JOSEPH A. TAFF.

INTRODUCTION.

The chalk and chalk-marl deposits of southwestern Arkansas were first described by Mr. R. T. Hill in Volume II of the Annual Report of the Geological Survey of Arkansas for 1888. In addition to giving a detailed description of the geology, Mr. Hill mapped the Cretaceous formations in which the chalks occur. Special attention was directed to their nature as true marine-chalk sediments.

In a chapter of the volume above cited Dr. J. C. Branner, then State geologist of Arkansas, briefly described the manufacture of Portland cement, and showed that the chalk of Arkansas compared favorably with the best English chalk as cement material. After further investigation of this region Dr. Branner published a paper on Cement Materials of Southwestern Arkansas, in the Transactions of the American Institute of Mining Engineers for 1897, pages 42–63, inclusive. The chalk and chalk-marls were found to be more extensive than had been before known. The deposits were more precisely located and mapped, and their thickness and structure were shown by sections. The differences in character of the separate chalk deposits and the lithologic variation of each, as well as their quality as cement materials, were brought out.

As a result of the work of the Arkansas survey public attention was called to these chalk deposits, and an extensive Portland cement plant was established at Whitecliffs, one of the type localities where the chalk is exposed in this region. At other localities, where lines of transportation cross or approach the chalk deposits, an active interest has been taken in them by property owners and investors of capital, and a demand has been created for fuller information. In response to this demand the following pages have been written.

GENERAL GEOGRAPHY.

The chalk region of southwestern Arkansas lies in a broad, low plain slightly inclined toward the southeast. The north edge of this plain in southwestern Arkansas is the southern limit of the Ouachita Mountain region. The border between the mountains and plain extends from the vicinity of Malvern, on the St. Louis, Iron Mountain and Southern Railway, westward through Hot Spring County, and the northern portions of Clark, Pike, and Howard counties, and across Polk County into Indian Territory. It is about 45 miles north of Rocky Comfort and nearly 20 miles northwest of Arkadelphia, and is therefore beyond the limit of the geologic map accompanying this report. The mountain ridges making the Ouachita Range near the border are elevated generally 1,000 to 2,300 feet above sea, while the higher levels in the plain to the south are not far from 700 feet above sea. The valleys in the mountains are deep cut, often more than 1,000 feet, while in the plain few have reached a depth of 200 feet. This plain, except where the land has been cleared for cultivation, is densely forested. For this reason, and since the plain is intricately dissected by small stream channels, the broad features of the plain are not readily recognized by the traveler. From occasional eminences near the northern border of the plain, and from the southern hills of the Ouachita Range, the broad and apparently level plain may be seen to the limit of view toward the south.

Ouachita River, with its large tributary, Caddo Creek, Little Missouri, West Saline, and Little rivers flow from the mountains into the plain. Little and West Saline rivers are tributaries to Red River, while the others flow into the Mississippi.

GEOLOGY.

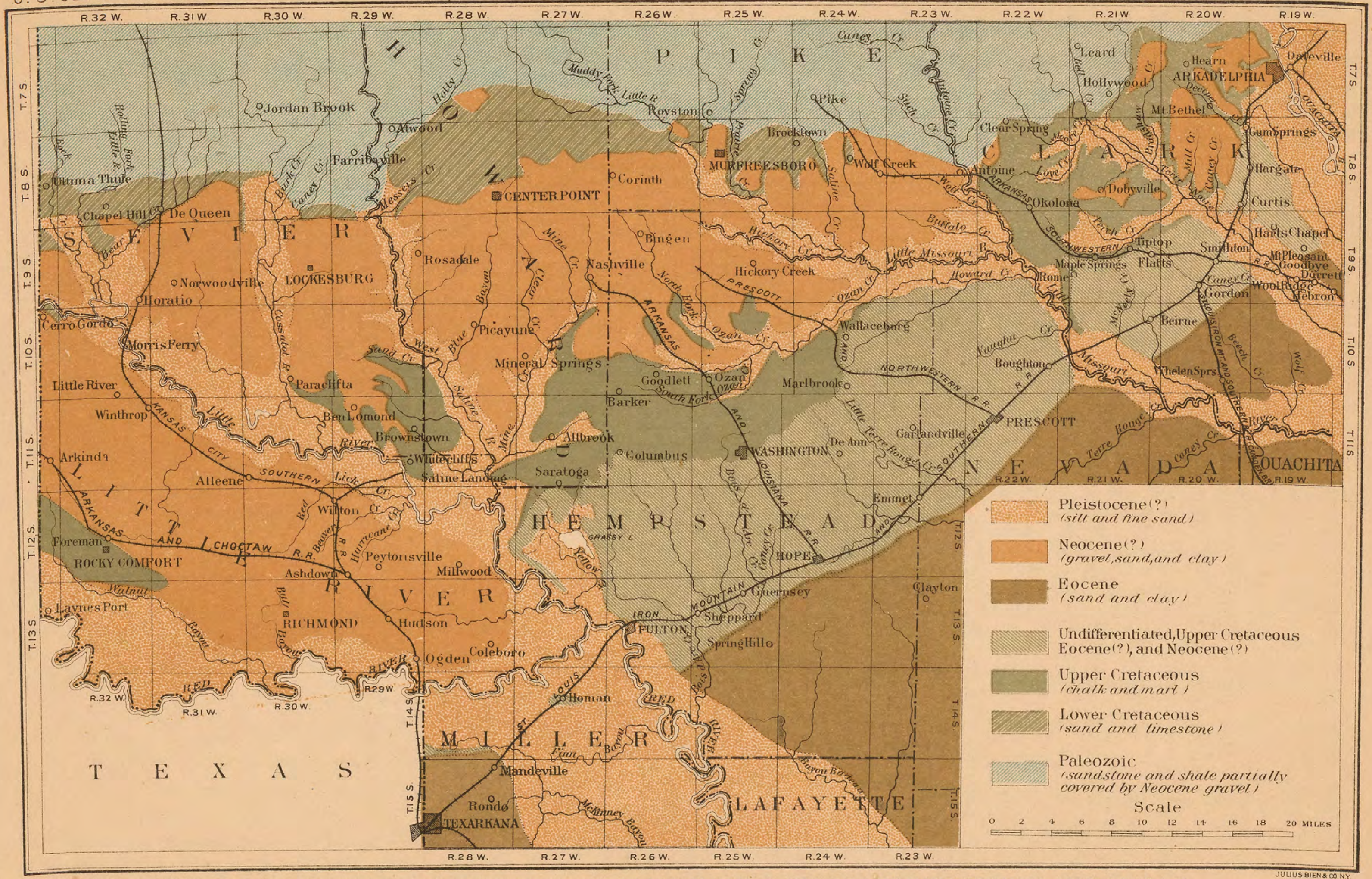
GENERAL GEOLOGY OF THE REGION.

The geologic map of the chalk region of southwestern Arkansas (Pl. XLVII) is based upon the maps of the geological survey of Arkansas. It combines the work of Mr. R. T. Hill, published in the volume above cited, and of Prof. G. D. Harris, in the Annual Report of the Geological Survey of Arkansas for 1892, Volume II, modified in the area of Upper Cretaceous rock according to observations by the writer.

The base map, furnished by the State land office and founded on the general land surveys, was not adequate for accurate geologic mapping. However, it was the only one available.

The widespread surficial deposits of Neocene and Pleistocene gravel, sand, and clay so conceal the Cretaceous deposits in the densely forested country of low relief that detailed geologic mapping can be done only at the expense of great labor and much time.

The rocks in the area represented on the accompanying map as



FROM PUBLISHED MAPS OF THE ARKANSAS GEOLOGICAL SURVEY WITH MODIFICATIONS

GEOLOGICAL MAP OF THE CHALK REGION OF SOUTHWESTERN ARKANSAS

BY JOSEPH A. TAFF

JULIUS BIEN & CO. N.Y.

undifferentiated Upper Cretaceous, Eocene, and Neocene were placed in the Eocene by Mr. Hill, though he explained that they were generally concealed by later gravel and sand. Mr. Harris determined, by fossil contents, that Mr. Hill's lowest Eocene formation, the Arkadelphia clay, as exposed at Arkadelphia, was Upper Cretaceous. From this evidence, without being able to map the Cretaceous-Tertiary parting, he considered the base of the Eocene to be approximately as shown on the map, south of the St. Louis and Iron Mountain Southern Railroad. It is therefore clear that this area of undifferentiated rocks contains Upper Cretaceous, and probably also some strata of Eocene age, concealed for the most part by Neocene gravels and sand.

Rocks in the area represented as Paleozoic have been classified provisionally by the Arkansas survey as Lower Carboniferous. They are sandstone and shale interstratified, and have not yielded fossil remains sufficient to determine their age with precision. Besides, they have been excessively folded and worn down and have been concealed, in the southern part especially, by gravel and débris, so that the stratigraphic succession of the beds can be interpreted only with much difficulty and uncertainty, if at all.

SKETCH OF THE GEOLOGIC HISTORY OF THE REGION, BEGINNING WITH CRETACEOUS TIME.

All of the Cretaceous rocks in this region, so far as known, were formed in the sea of materials brought in from the land, and of the shells and skeletons of sea animals.

The Cretaceous sea was open toward the south and east and extended into the region of the Gulf of Mexico. Its shores ran generally east and west, parallel with the Ouachita Mountain region in Arkansas and Indian Territory, and curved toward the southwest in Texas. The earliest shore line of this sea of which the rocks show record is in central Texas, 300 miles southwest of Arkansas. When the shore line was at this point all of the region tc the north of it was land. As the surface of the country became lower, in part by being worn down by erosion and in part by the subsidence of the land, the shore moved northward. Several times during the advance of the sea subsidence of the land ceased for a while and the shore line was temporarily stationary, or even, owing to elevation of the general land surface, moved southward. During one of these periods near the middle of the Cretaceous, the shore receded many miles southward, but only to return again farther north than before. During the slow northward progression of the shore rock materials from the shore were washed into the sea, forming sediments. The sand, pebbles, and other coarse materials were not carried to a depth beyond reach of the waves and strong currents and they formed the conglomerate and sand. Farther out, in greater depths of water, clay and lime were deposited, which formed beds of clay, marl, limestone, and chalk.

At the end of the Cretaceous period the land was elevated and the sea returned southward. When the Cretaceous rocks were elevated into land they were soft, as indeed most of them are at present, and during the long interval since that time they have been worn down by erosion and entirely removed from a large tract of country north and west of the present Cretaceous border.

In the elevation of the Cretaceous rocks into land they were tilted slightly in the direction of the retreat of the sea, so that the beds of rock now dip toward the south and southeast at the low inclination of 40 to 50 feet per mile.

At a relatively recent time the Cretaceous region of Arkansas and a part of that in Texas have been overrun by bodies of water having sufficient current and depth to transport and form large deposits of gravel, sand, and clay. The areas of these gravel deposits are shown upon the geological map as Neocene(?). They cover a large part of the highland of the region.

From Neocene time down to the present the streams have worn through these beds of gravel and sand or have modified them. They have made wide valleys through the Cretaceous chalk and marls, as well as gravel deposits, and in these valleys they have deposited finer sediments, which are illustrated upon the geologic map as Pleistocene. The minor details of the topography of the area are thus due chiefly to stream action in recent time.

THE CRETACEOUS FORMATIONS.

Previous to the present investigation of the Arkansas chalk deposits, the writer, while a member of the Texas geological survey, had occasion to survey the Cretaceous rocks of northern Texas and to study the chalk formation, which is a member of them, from the vicinity of San Antonio, Tex., to Red River west of the Arkansas region.

In order that the Cretaceous rocks of southwestern Arkansas may be clearly understood, it will be necessary to discuss them in connection with the deposits of northern Texas, the nearest locality where all the formations are completely exposed.

LOWER CRETACEOUS.

The Lower Cretaceous is represented in the Arkansas region by two formations — the lower composed of sand and the upper chiefly of limestone. The occurrence of the lower formation is shown upon the map in the several areas near the north side bordering the Paleozoic. The succeeding deposits of the Lower Cretaceous are known to outcrop in this region only in a single small area at Cerro Gordo, on the Little Missouri River, being elsewhere concealed by the post Cretaceous gravel and sand deposits and by overlap of the Upper Cretaceous.

The lower formation, known as the Trinity sand, is composed chiefly of fine, clean sand with pebbles at the base, and in some localities, bowlders which have been derived from Paleozoic rocks similar to those which occur in the vicinity. In places this sand contains quantities of fossil trees which were drifted into the sea from the land at the time the sand was formed. The Trinity sand is the beach and near-shore deposit of the Lower Cretaceous sea in the region of Arkansas and Texas. It is found at the base of the Cretaceous resting upon eroded surfaces of Paleozoic rocks and has a continuous outcrop from Murfreesboro, Ark., westward to the vicinity of Ardmore, Ind. T., and thence southward to central Texas west of Austin.

As the sea progressed northward, successive beds of marl and lime sediments were laid down in the deeper water, with their edges coming successively upon this sand toward the shore. Thus a large body of the lower part of the succeeding lime formation laps upon and grades into near-shore sand and does not occur in the northern part of the Texas region and in Arkansas. Moreover, the limestone formations that are found in Arkansas and in southern Indian Territory become

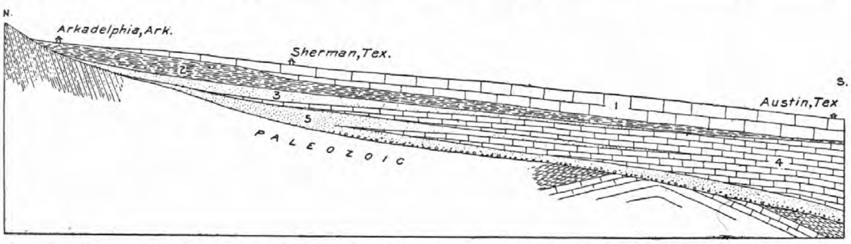


FIG. 57.—Diagrammatic section of the Cretaceous rocks in northern Texas and southwestern Arkansas. 1, white chalk; 2, blue marl; 3, sands at base of Upper Cretaceous; 4, Lower Cretaceous limestone; 5, sand at base of Lower Cretaceous.

much thicker southward in Texas toward the interior of the Cretaceous sea. The relations and structure of the Cretaceous formations are illustrated in fig. 57.

UPPER CRETACEOUS.

At the beginning of the Upper Cretaceous the region north of the Brazos River in Texas was elevated into land or brought very near the shore, but the rocks of the Lower Cretaceous were but slightly eroded. The evidence of the elevation of the land and the retreat of the sea southward is to be found in the sandy, shallow water deposits that mark the beginning of the Upper Cretaceous, which are resting upon the highest eroded surface of the Lower Cretaceous. These sandy deposits are thick in north Texas and in Indian Territory, where they show that the action of waves aided in the formation of their beds, and contain leaves and stems of forest trees which were washed in from the nearby land. Toward the south these sandy rocks grade into marl and lime sediments, which rest upon the smooth undisturbed top of the Lower Cretaceous. This sandy lowest member of the Upper Cretaceous is concealed in Arkansas by a post-Cretaceous deposit of gravel and sand.

Limy clay and marl overlie the basal sand of the Upper Cretaceous, and are in turn succeeded by the chalk.

The marl below the chalk is a continuous formation, which increases gradually in thickness from Austin, in central Texas, to the vicinity of Whitecliffs, in Arkansas. At the former locality it is about 30 feet, while at the latter it is nearly 300 feet in thickness.

THE CHALK—ITS ORIGIN, CHARACTER, AND EXTENT.

The white chalk is exposed from Austin northward to Sherman, Tex., through a distance of nearly 250 miles, without appreciable change in its thickness of nearly 600 feet and with a very slight variation in texture, color, and nature of the material.

When the chalk in this region was formed, the shore of the Cretaceous sea had passed so far north of the region that only small quantities of sediment were brought from the land. It is supposed that the sea was deep; at any rate, the bottom was below the reach of the waves. It is considered that during a long extent of time the conditions of the sea in this region remained nearly constant, while the limy skeletons of countless microscopic organisms settled to the bottom and formed the chalk.

In the vicinity of Sherman, a few miles south of Red River, the chalk formation turns eastward and continues down the south side of the river valley through Grayson, Fannin, Lamar, and Red River counties and into the northwestern part of Bowie County. From the last locality the chalk passes beneath the bottom land of Red River to Rocky Comfort, in Arkansas. Farther east it comes to the surface at Whitecliffs, on Little River, and Saline Landing on the West Saline River. In the Arkansas region it is known as the Whitecliffs formation.

The outcrop of the chalk from Sherman eastward into Arkansas is nearly parallel to the Cretaceous shore, which runs east and west along the old Ouachita Mountain Range. The increasing proximity to shore is indicated by the trend of the Cretaceous rocks, and by the change in character of the chalk sediments which bear toward it.

The lower part of the thick chalk formation of north Texas changes to marl in the vicinity of Sherman, and still farther east higher beds successively become chalky marl, so that within a comparatively short distance only the upper part of the chalk formation as it occurs farther south is true chalk. In other words, the white chalk transgresses upward in the series of Cretaceous rocks from the vicinity of Sherman, Tex., eastward into Arkansas.

The fossils of the main chalk which are not found below it in north Texas, south of Sherman, occur in the chalky marl beneath the chalk from the vicinity of Paris, Tex., eastward. The fauna, including the characteristic species of fossils, such as *Exogyra ponderosa*, *Gryphæa*

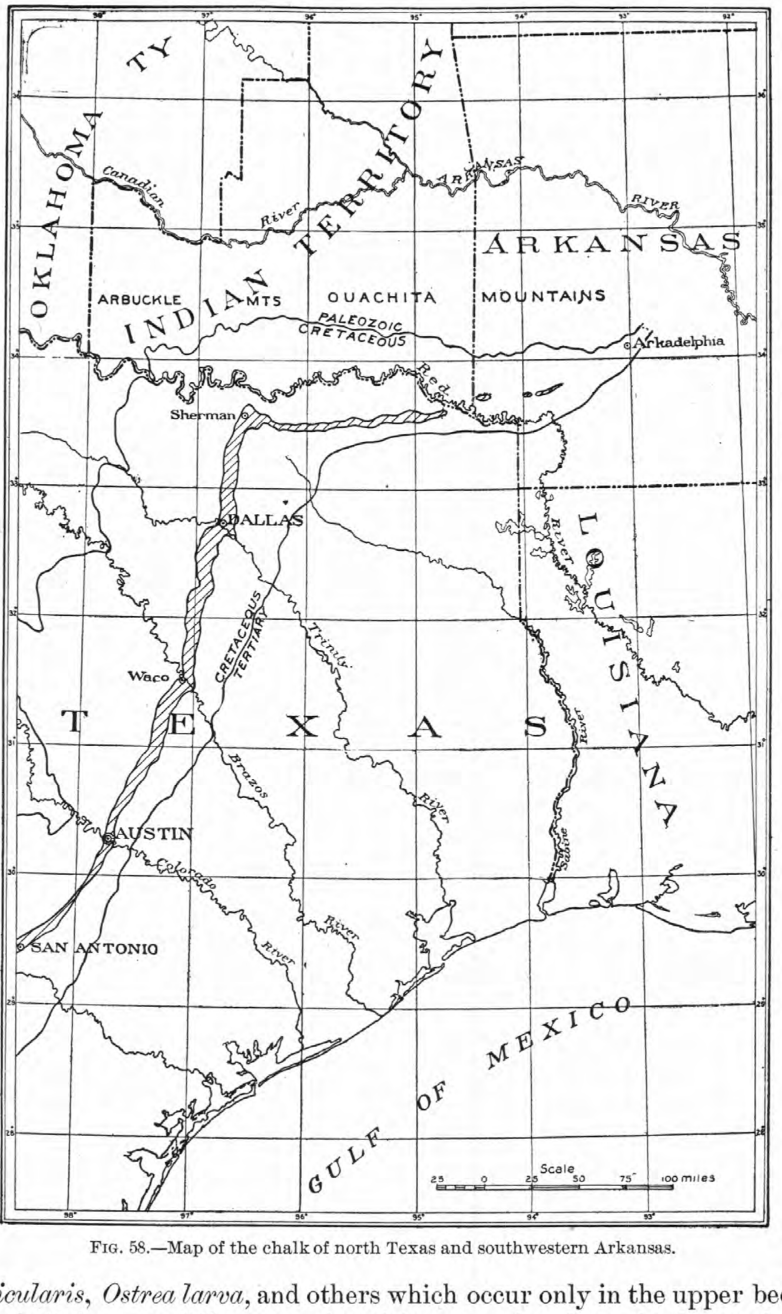


FIG. 58.—Map of the chalk of north Texas and southwestern Arkansas.

vesicularis, *Ostrea larva*, and others which occur only in the upper beds the chalk in central Texas are found in great abundance in the marl at of the base of and beneath the white chalk in southwestern Arkansas.

This white chalk grows thinner in outcrop northeastward as it approaches the Paleozoic border and elevated mountain districts until it ends in chalky marl near the center of the Cretaceous area of southwestern Arkansas. Fig. 58 is intended to show the location of the white chalk from central Texas to southwestern Arkansas.

The Upper Cretaceous of southwestern Arkansas, as indicated on the geologic map (Pl. XLVII), includes the exposed chalk as well as the marls both above and below it. The chalk outcrops of the region are illustrated in figs. 59, 60, 62, 63, 66, and 69.

The marl above the white chalk, in Texas, continues upward through many hundred feet to the top of the Cretaceous.

A second, thinner and less pure chalk formation occurs in southwest Arkansas in the marl above the first white chalk of the Whitecliffs formation. In distinction to the first, this chalky bed is known as the Saratoga chalk or chalk-marl. The name is from the town of Saratoga, Hempstead County, Ark., near which it is typically exposed. It is separated from the white chalk by about 200 feet of blue limy marl, and is succeeded by greensand and clay marls, which extend to the top of the Cretaceous in the Arkansas region.

DETAILED DESCRIPTIONS OF THE CHALK AND CHALK-MARL.

WHITECLIFFS FORMATION.

The Whitecliffs formation in Arkansas occurs exposed in three areas. These are in the vicinities of Rocky Comfort, Whitecliffs, and Saline Landing, for which each area is respectively named. The location of these areas is shown in the maps accompanying the detailed descriptions of each. The formation is continuous from area to area beneath Neocene and Pleistocene deposits.

The formation is a white chalk which occurs bedded between formations of marl, into which it gradually merges.

In the westernmost area in this region the exact thickness of this formation could not be accurately determined, but it is estimated to exceed 100 feet. At Whitecliffs nearly 100 feet of the chalk is exposed and the top of the formation is concealed. At Saline Landing a part of the formation also is concealed. In the eastern part of Saline Landing area, however, it is less than one-half the thickness exposed at Whitecliffs. In the vicinity of Okolona, 30 miles farther east, where the strata are next exposed, the white chalk does not occur. Thus it is seen that the Whitecliffs formation occurs as a wedge with its thick end toward the west and coming to an end near the middle of the Cretaceous region of southwestern Arkansas.

ROCKY COMFORT AREA.

Location and character of the surface.—The Rocky Comfort chalk area lies in the rudely rectangular block of land between Rocky Comfort and Walnut Bayou. It is approximately 2 miles long in a northeast-southwest direction and nearly a mile wide. Rocky Comfort is near the center of the northeast end.

The contact line at the base of the chalk on the northwest side, across parts of secs. 21 and 29, is only approximately located, as it is concealed by deep black soil which covers the white chalk and underlying

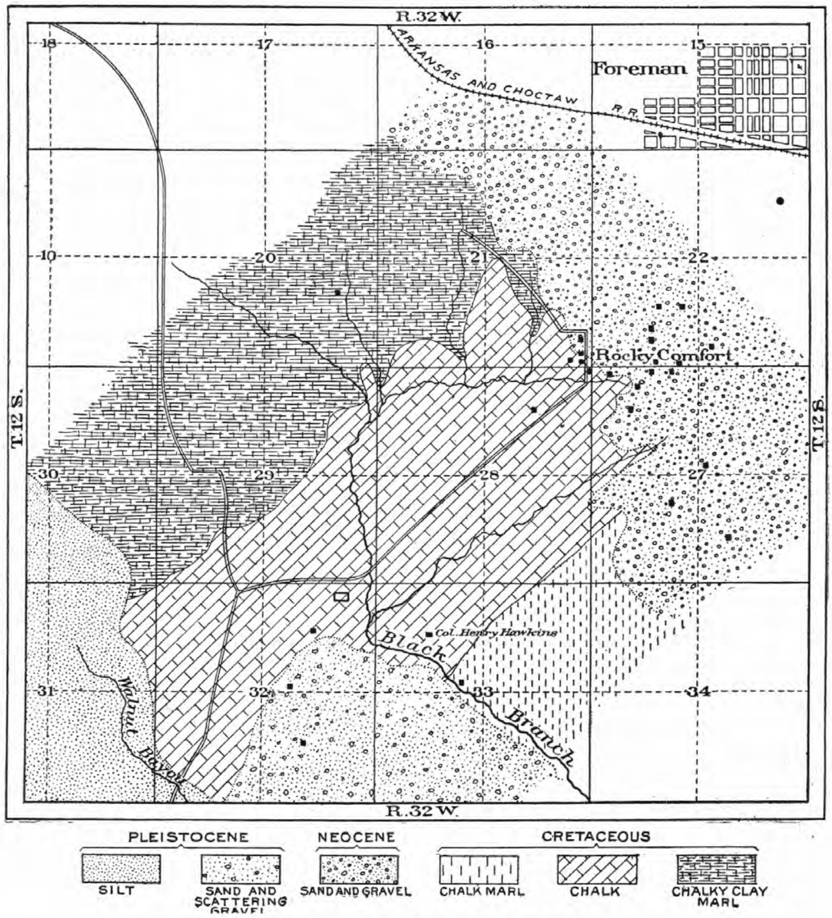


FIG. 59.—Map of the Rocky Comfort area.

blue marl alike. The parting line at the top of the chalk in secs. 32, 27, and 28, T. 12 S., R. 32 W., is also concealed in places by gravel and soil.

Between Black Branch and Walnut Bayou the uppermost beds of the chalk formation are overlain and concealed by a hummocky deposit of second bottom sand and gravel. This second bottom is elevated a few feet above the overflow limit of Red River, is nearly level, and where uncultivated is covered by dense and tall timber.

The outcrop of the chalk terminates abruptly on the southwest side, where it has been worn down by Red River and then covered by its bottom-land deposit of fine silt. At high flood Red River overflows to the chalk contact east of Walnut Bayou.

East of Rocky Comfort the chalk is concealed by highland deposits of gravel, sand, and clay of variable but not great thickness. These are the Neocene and Pleistocene deposits, which occupy a large part of the region and are spread over the chalk formation between Rocky Comfort and Whitecliffs Landing on Little River. In places this surficial deposit is thin, and it is reported that in small areas in the region toward Richmond the black soil of the chalk or marl is entirely uncovered.

The strike of the chalk eastward follows an almost straight belt from Rocky Comfort to Whitecliffs Landing beneath later deposits of gravel, sand, and silt. In this belt no true chalk outcrops are known to occur.

East of the chalk outcrop in the vicinity of Rocky Comfort the gravel and sand deposits are generally of considerable thickness, and it is not necessary to consider the chalk beneath them.

The topography of the chalk belt and of the adjacent marls is gently undulating, and the valleys of Black Branch and its tributary streams are not well defined except near the source of those streams which flow from the more elevated gravel deposits on the east side. These small streams near their sources sap the chalk from beneath the gravel and sand by solution and headwater erosion, thereby cutting short valleys 40 to 60 feet in depth. The lower ridges of chalky land rapidly decline from gravel tongues between the valleys to low divides toward the interior of the chalk area. The chalk country between Black Branch and Walnut Bayou is practically flat, and west of the "line road" is covered in part by a thin mantle of second-bottom silt.

The area underlain by the chalk and its underlying chalky marl is occupied almost entirely by cultivated fields, while the bottom land to the west of the chalk area and the highland gravel to the east have not been denuded of the original forest except to a very limited extent.

The chalk and the chalk-marl above and below it dip toward the southeast in this area, as do the same deposits elsewhere throughout southwestern Arkansas. A deep well drilled in the southeast corner of section 28, for instance, would pass through the entire chalk of the Rocky Comfort area and penetrate the marl which crops out in the black land belt northwest of it.

The thickness of the true chalk in this era is not known, but is estimated to be about 100 feet.

Description of exposures.—The chalk which outcrops in the vicinity of Rocky Comfort is remarkably uniform in physical appearance. It is massive, white, sufficiently friable to soil the fingers, and thin pieces may be broken in the hands, but the hammer is required to pulverize the massive rock. On exposure the chalk breaks into conchoidal fragments which weather to lumps and finally become chalky dust. In the 50 to 60 feet exposed in the hillsides south of the town the bedding is scarcely perceptible.

The composition of fresh chalk from the bed of the branch at the base of the exposure is given in analysis No. 4, Table III (p. 735), while No. 3 shows that exposed in the ditches, 55 feet higher. The former is not many feet above the base of the true chalk and the latter belongs near the middle. This chalk is, in physical appearance, like that of Whitecliffs, and a comparison of the analyses with No. 9, that of the chalk from Whitecliffs quarry, shows them to be practically the same in chemical composition.

The lower beds are exposed by the road in the SE. ¼ of the SE. ¼ of sec. 21, T. 12 S., R. 32 W., also near the middle of section 21, with chalky marl cropping below. These basal beds are more marly and siliceous than those higher in the formation south of Rocky Comfort.

From the center of section 21 to the "line road" in the SW. ¼ of section 29 the chalk is concealed beneath residual black soil. At the latter locality the chalk is well exposed in ditches and on high ground along the road almost through the SE. ¼ of the SW. ¼ of sec. 29. The lower beds of the formation are also exposed in the hill and bluff facing the river bottom in the NE. ¼ of the NE. ¼ of sec. 31.

From the base of the chalk downward there is a transition zone of bluish chalk-marl which grades down into still less chalky clay marls. This transition chalk-marl is exposed at the contact in the SW. ¼ of sec. 29 and in deep ditches on the hill slopes below the Hopson graveyard in the NE. ¼ of the NE. ¼ of sec. 30.

Analysis No. 2, Table III, is of a specimen of the transition chalk-marl from the latter locality. While the analysis shows that the marl contains 25 per cent of silica, sand is not visible.

From sec. 30 northward to the Holman place, near the center of sec. 18, the marl is generally concealed by its residual soil. Grayish-blue, sandy, chalky marl, partially indurated at the surface, crops out at the Holman House and in gullies 500 feet farther west. This marl contains numerous specimens of the large oyster *Exogyra ponderosa* besides the small variety of *Gryphæa vesicularis* and the other small shells so abundant in the marls below the chalk in the vicinity of Whitecliffs. This chalky marl is perceptibly more sandy than that higher in the section immediately below the true chalk.

The crumbling edges of the chalk deposits crop out in the low bluff of Walnut Bayou bottom from the NE. ¼ of the NE. ¼ of sec. 30 southward to the extreme south end of the chalk area in the SE. ¼ of the SW. ¼ of sec. 32.

Excellent exposures of the chalk occur in and near the road in the SW. ¼ of the SW. ¼ of sec. 32. The analysis of this chalk is given in No. 1 of the table. The chief difference between this and the other samples of the purer chalk analyzed is that it contains much more clay. The only perceptible physical difference, however, is that it is a little harder.

A rather large exposure of white chalk, of beds near the top of the formation, appears on the Col. Henry Hawkins's place, in the NW. ¼ of sec. 33. About ¼ mile southeast of the house in the SE. ¼ of the NW. ¼ of sec. 33, the top of the true chalk and the base of the succeeding chalky marl is exposed. A thin mantle of gravel conceals part

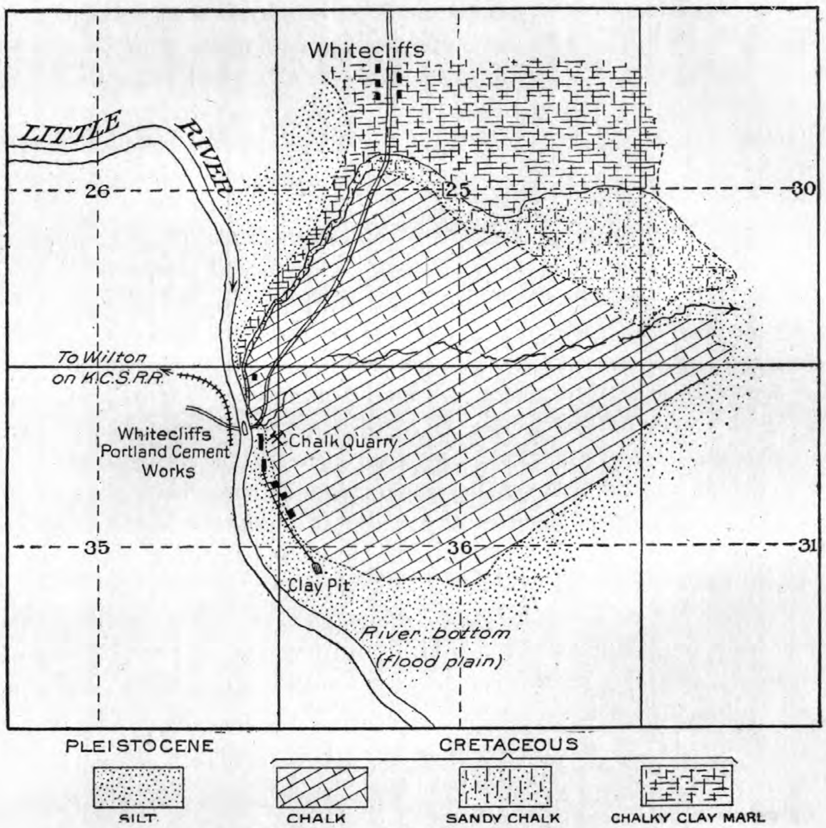


FIG. 60.—Map of the Whitecliffs area.

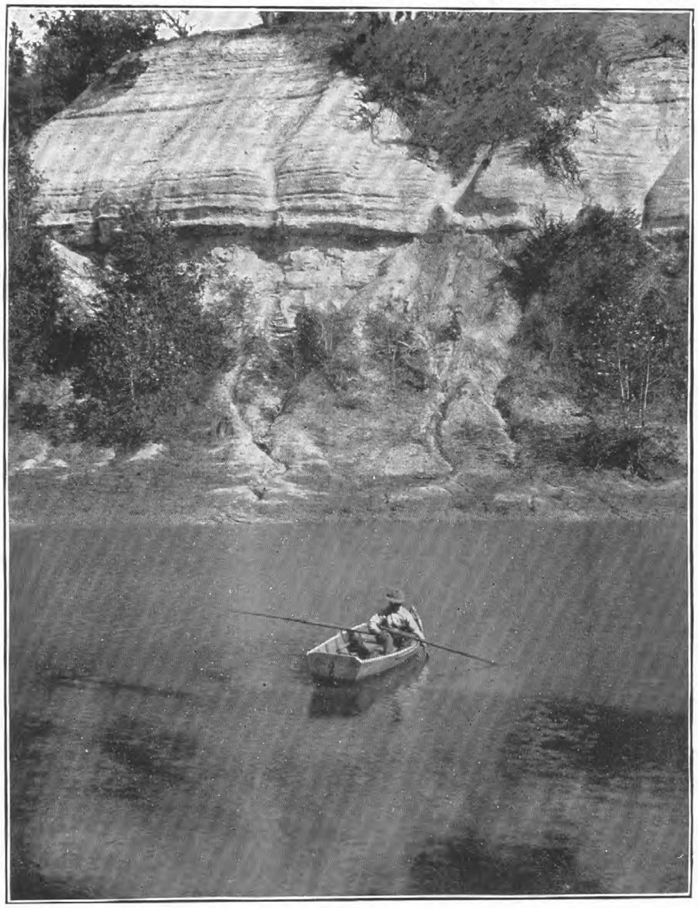
of both the chalk and the marl. The upper layers of the chalk are also exposed south of the branch, in the SE. ¼ of sec. 28.

There are smaller exposures of chalk in this region, but it is believed that those above described are typical.

WHITECLIFFS AREA.

Location and surface features.—The boundaries of this area were established by traverse surveys, checked on section and fractional section corners, and the errors of location are small. The map is shown in fig. 60.

The true chalk here exposed occupies parts of secs. 25, 26, 35, and 36, T. 11 S., R. 29 W., and secs. 30 and 31, T. 11 S., R. 28 W., and covers an area of about 600 acres.



CHALK BLUFF AT WHITECLIFFS LANDING.

The chalk at Whitecliffs forms a low table-land, elevated 25 to 100 feet above the bottom land on the east, south, and west sides, and slightly inclined toward the southeast. The highest point of the table-land is at the west side and extends nearly half a mile north of the Whitecliffs Portland Cement Works, where the chalk outcrops in cliffs and bluffs in the face of an escarpment from 100 to 130 feet above Little River. From the cement works completely around the south and southeast sides of the area to the extreme east end, the chalk stands in a more or less irregular bluff 20 to 50 feet high, partially covered by soil and gravel débris. The silted bottom lands of Little and West Saline rivers extend up to the base of the bluff and conceal the lower part of the chalk. The lower part of the chalk, as exposed, makes a low and indistinct escarpment on the north side of the area from the road south of the village of Whitecliffs to the southeast quarter of sec. 25, T. 11 S., R. 29 W. The lower sandy member of the chalk makes a wide bench northeast of the chalk and is about 20 to 40 feet above the adjoining creek bottom. Near the center of section 25 the outcrop of sandy chalk contracts and joins the low escarpments of the chalk proper, and so continues westward and southward to the cement works.

From the vicinity of Whitecliffs post-office the upland becomes rapidly broader northward, attaining a width of about 6 miles, and continues northward between the Cossatot and West Saline rivers, but the true chalk is not found north of the village.

A large part of the chalk of the Whitecliffs area is covered by a thin mantle of Neocene gravel and sand. In places this gravel may attain a thickness of several feet, but it is believed that it will nowhere interfere seriously with the removal of the chalk. The chalk is also concealed in places, especially near the border of the area, by its own residual soil, with scattered pebbles or a very thin layer of gravel.

A small stream, which has its source near the edge of the cliff in the southwest corner of section 25 and flows eastward, has formed its shallow, swampy valley chiefly by the solution of the chalk. As the rock is disintegrated and removed the gravel descends, covering the slopes of the valley. Another stream, still smaller, which rises in the northwest corner of section 26, and joins Little River at the ferry, descends 100 feet in less than one-fourth of a mile, and has cut a narrow gulch, up the side of which the road passes over the exposed edge of the chalk to the top of the table-land.

Chalk and associated chalk-marls.—The most noteworthy exposure of chalk in southwestern Arkansas occurs in the cliffs overlooking Little River from the east side in the northeast corner of sec. 35, T. 11 S., R. 29 W., immediately above the ferry. Pl. XLVIII is a view of the central and best exposed portion of the cliff.

From the brink of the cliff down to the water level is 115 feet and about 15 feet of chalk is exposed at a higher level by the road which leads from the cement works. The following is a detailed section, beginning at the top, of the chalk and marl in the cliff.

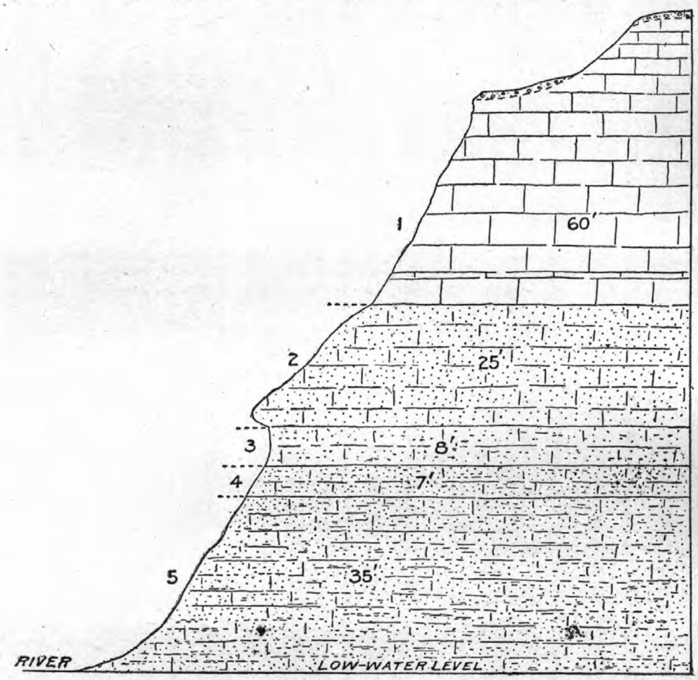
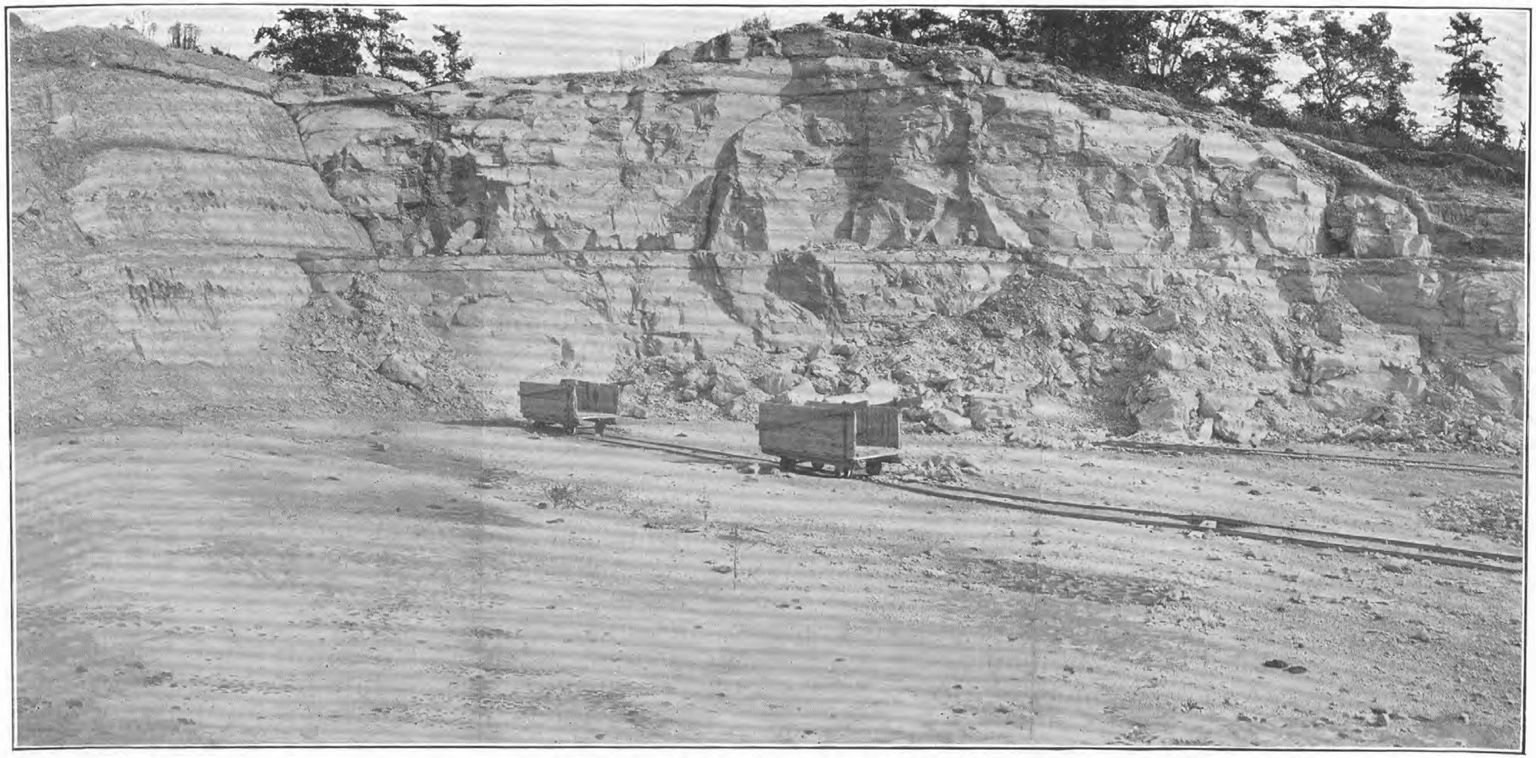


FIG. 61.—Section of the chalk at Whitecliffs Landing (see section below.)

Section at Whitecliffs Landing (see fig. 61).

	Feet.
1. Massive, creamy white chalk, in beds from a foot to about 10 feet thick, separated by thin partings of very slightly laminated chalk. The variation in the character of the chalk from bed to bed is not perceptible on physical examination, and the stratification planes are not clearly defined except upon partial weathering of the rock. Analysis No. 7, Table III (p. 735), is of specimens in the lower part of this chalk, while No. 9 is an average of specimens from each bed in the lower half as exposed in the quarry back of the cement works. Plate XLIX is a view of this quarry. Analysis No. 8 is from about 10 feet below the top as exposed by the road opposite the cliff	60
2. Massive, dull-bluish-white, siliceous chalk. Slightly harder than the pure chalk of 1. This chalk is practically without indication of bedding, and because of its hardness it projects in a steep bench overhanging the less chalky and friable beds below. Analysis No. 6 shows that this chalk contains nearly twice as much silica as the chalk above. This bed occurs in the bench beneath the quarry at the cement works and passes to the level of the river bottom near the clay pit south of the works. An outcrop occurs also near the middle of the bluffs north of the cliffs, spreading out at the surface in the cultivated fields one mile southeast of the village of Whitecliffs. It occurs near the level of the river bottom at the southeast side of the mapped area	25



CHALK QUARRY AT WHITECLIFFS LANDING.

	Feet.
3. Massive, very siliceous, dull-blue argillaceous chalk-marl. This bed contains more than twice as much sand and nearly three times as much clay as the overlying bed No. 2. The rock is quite friable and weathers in recesses beneath the siliceous chalk	8
4. Bluish, sandy, chalky marl, containing great numbers of the fossil shell *Gryphæa vesicularis* variety. Except for the abundant fossils this rock would be classed with 3, though it is probably slightly more sandy. Typical fossils from this bed are illustrated in Pl. L	7
5. Bluish, sandy, chalky marl, gradually increasing in sandiness from the top downward to the level of the river. This bed contains fossils of the *Gryphæa vesicularis* variety, but not so abundantly as in 4; and also many fossils of the large and heavy oyster *Exogyra ponderosa* as well as others common to the Upper Cretaceous marls	35

The lower 30 to 35 feet of the white chalk of 1 is freshly exposed in the quarry at the cement works opposite the landing, as illustrated in Pl. XLIX.

The top of the bluish-white chalk of 2 forms the bench beneath the quarry and occurs at the base of the bluff southeast of the landing.

The sandy chalk members 3, 4, and 5 rise gradually northward from the lower part of the cliff and are found in the high land between the villages of Whitecliffs and Brownstown. The very abundant fossils of the *Gryphæa vesicularis* variety may be seen weathering in the ditches and at the top of the escarpment northwest of the village of Whitecliffs.

The fossil *Gryphæa vesicularis* variety is illustrated, natural size, in Pl. L. These fossils are found in this chalk region only in the bluish chalky marl beneath the white chalk. They may be relied upon as a definite marker for the formation immediately below the chalk.

One-half mile west of Dr. Coats's house, in the NW. ¼ of sec. 23, T. 11 S., R. 29 W., *Gryphæa vesicularis* variety bed No. 4 is exposed at the top of the bluff and below it is the following section, well shown in deep gullies down to the level of the valley:

Section of marl below the Whitecliffs chalk.

	Feet.
1. Sandy, chalky marl. Dull bluish when not weathered, becoming grayish, or whitish yellow after long exposure. It contains numerous specimens of the large oyster *Exogyra ponderosa*, besides *Ostrea larva* and many other fossils common to the Upper Cretaceous marls. The upper half of this member is No. 5 at the base of the cliff at Whitecliffs Landing	60
2. Blue clay-marl containing some large oysters as above, and less lime than No. 1, and much more clay	30
3. Dark-blue, gritty, greensand marl with scattering smooth round pebbles of black and white quartz 1 inch and less in diameter	10
4. Blue clay-marl down to the level of the bottom land, exposed	15

This section is located about 2 miles north-northeast of the chalk cliff which is in the NW. ¼ of sec. 35, and the sandy marl bed, which is here about 100 feet above the river, is at the water level at the cliff. This marl bed with the associated marls and chalks above, which are conformable with it, dips toward the southeast at the rate of about 50 feet per mile. The base of the chalk at the north side of the chalk area is fully 50 feet above the river bottom. At the south side, a mile distant, it is at the level of the bottom. There may be local variations in the dip of the beds, but the general dip is estimated to be nearly 50 feet per mile toward the southeast.

SALINE LANDING AREA.

Location and surface features.—Saline Landing was once the port for the shipment of cotton from this region and stood practically at the head of navigation for small steamers on West Saline River. At the present time it is known only by name and association with the McDaniel place, an old homestead which adjoins it on the east. Saline Landing is at the extreme west end of the easternmost area of true chalk in this region, and is separated from the chalk of Whitecliffs by a space of 4½ miles. The chalk deposits of the two localities are parts of the same formation and are directly connected beneath the river bottom land.

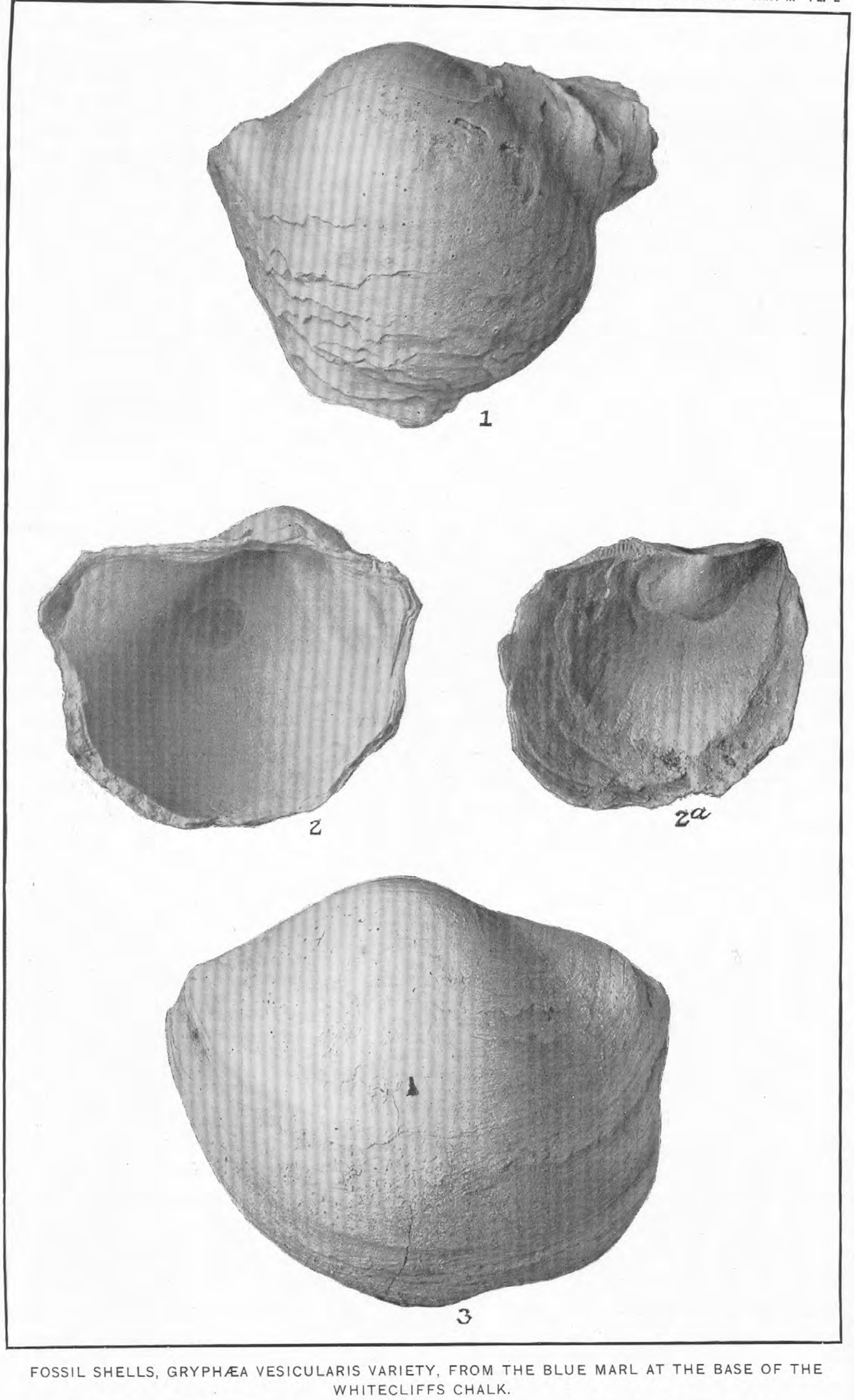
The chalk area of Saline Landing was located by traverse surveys checked on section and half section corners, and the mapping is approximately correct.

It extends with practically continuous exposure from the chalk bluff at Saline Landing in the south half of sec. 35, T. 11 S., R. 28 W., to sec. 14, T. 11 S., R. 27 W., is thus about 7 miles in length, and has an average width of about one-third of a mile. The map of this chalk area is given as fig. 62.

The chalk area is bounded on the north side by the silt deposits of Plum Creek, which conceal the lower beds of the chalk formation along the entire area. The soil of Plum Creek bottom, which has been transported from the soils of the chalk and marl bordering the valley, so resembles the soil of the chalk that the line between the two can be only approximately located through a part of its course. The top of the chalk, which is on the south side, is partially concealed by black residual soil.

The entire area, except in the vicinity of Saline Landing, where the surface is flat, slopes gradually toward Plum Creek bottom and is crossed by numerous swales in which water flows only in rainy weather.

The forest has been removed from the entire area, which is now occupied by inclosed or cultivated fields. When the forest covered the land the chalk was almost entirely concealed beneath its soil, but during the cultivation of the land the soil has been removed by erosion from the steeper slopes and from many of the small divides between the main streams, producing chalk barrens. On the level spaces and in the valleys the residual soil resting on the chalk is dense black and often several feet in depth.



FOSSIL SHELLS, GRYPHÆA VESICULARIS VARIETY, FROM THE BLUE MARL AT THE BASE OF THE WHITECLIFFS CHALK.

1 and 3, Outside view of large valve; 2, inside view of large valve; 2a, outside view of small valve of 2. Natural size.

Description of the chalk exposures.—As stated above, the base of the chalk is not exposed in this area, though the lower sandy member crops out in sections 21 and 22, toward the source of Plum Creek.

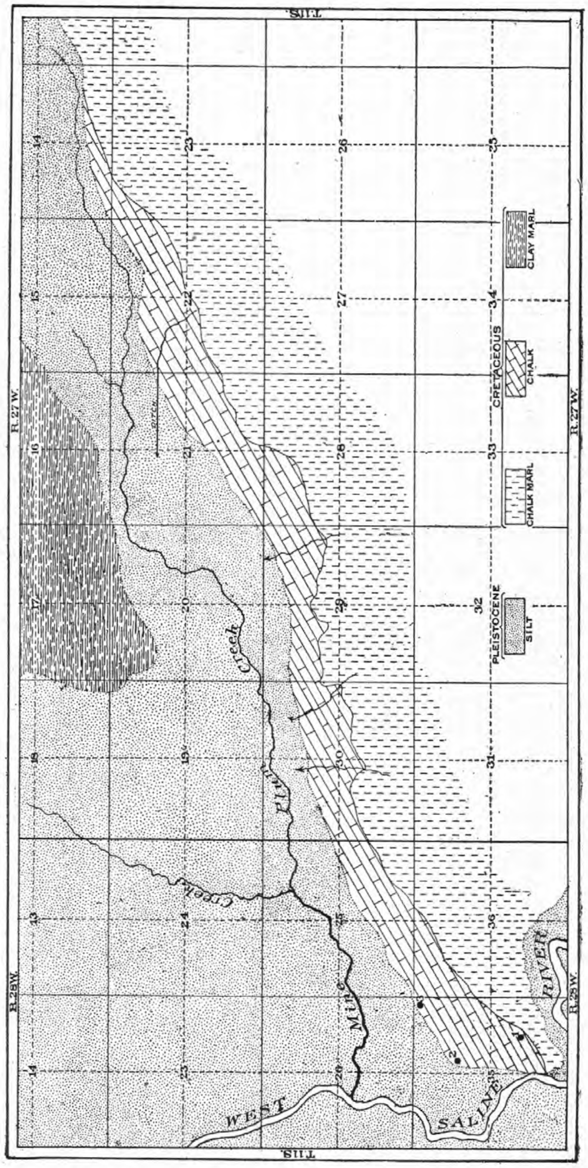


FIG. 62.—Map of the Saline Landing area.

These outcrops occur in the border of the creek bottom, within less than 1 mile of the exposures of fossiliferous blue marl cropping out in the north side of Plum Creek, in sections 15 and 16. The structure of the rocks shows that this marl belongs not more than 50 feet below the base of the chalk.

The chalk at the top, as exposed in many places in the south side of the area, grades up into blue clay-marl through 20 to 30 feet of marly chalk and chalky marl. This gradation is especially well shown in the chalky, barren hill slopes near the Columbus Mineral Springs road, in the south side of sec. 14, T. 11 S., R. 27 W.

The thickness of the chalk in the southwestern part of the area is not known, as its lower portion is concealed. Near the northeast corner of sec. 22, T. 11 S., R. 27 W., the full thickness of the purer chalk above the lower sandy member will not exceed 25 feet. Near the east side of sec. 14, T. 11 S., R. 27 W., the entire chalk bed passes beneath the bottom of Plum Creek.

The divide between the sources of Plum and South Ozan creeks is flat, and the chalk deposits are entirely concealed beneath the soil in the cultivated fields. The crop of the chalk, as indicated by the structure of the rocks, would extend northeastward through secs. 7, 8, 5, 4, and 3, in T. 11 S., R. 26 W., and into Ozan Creek bottom. The location of this probable outcrop is shown in fig. 63.

By the report of Mr. H. H. Hanna, a reputable farmer, wells in the NW. ¼ of the SW. ¼ of sec. 35, T. 10 S., R. 26 W. penetrate a few feet of "white lime rock" and enter blue clay marl after passing through 10 to 13 feet of the surface deposit of red sandy clay. It is very probable that this "white lime rock" is a part of the lower member of the chalk. Between Mr. Hanna's place, located as above, and the Little Missouri River, the Cretaceous rocks in the strike of the chalk are concealed by the bottom land of Ozan Creek.

It would appear that the chalk deposits of this region grow thinner eastward, and gradually change in nature from true chalk to chalk-marl. Where the formations emerge from beneath the bottom land in the vicinity of Okolona, east of the Little Missouri River, and nearly 30 miles east of the exposures on Plum Creek, the lower sandy member of the chalk is present with its abundant and characteristic fossil, *Gryphæa vesicularis* variety, but the position of the purer chalk above it is occupied by a blue chalk-marl. The outcrop of this formation is outlined in fig. 66, which shows the Okolona area of chalky marl.

The chalk bluff at Saline Landing is 20 feet in height (above low water) and about 300 feet long. When visited by the writer the river was at flood, so that less than 10 feet of the rock was exposed to view. The lower portion of the chalk as then exposed is white, massive, and without distinct bedding planes, the upper 5 feet being weathered to a chalky earth. Specimens of the chalk were collected from the water level, which would be near the center of the bluff at the usual low stage of the river. Analysis No. 10, Table III (p. 735), of this chalk is nearly the same as No. 6, which is of the lower sandy member of

Whitecliffs, and suggests that the exposure at Saline Landing is in the lower part of the chalk formation in this area.

East of Saline Landing the chalk country is flat and the rock is concealed by the deep soil in the cultivated fields. The chalk is said to be exposed in deep ditches, one-fourth mile southeast of the residence on the McDaniel place, but on account of the water the report could not be verified.

Three artesian wells have been drilled on the McDaniel place upon the chalk; the one at the house near the landing has a record, according to Dr. Branner's published report, as follows:[a]

Record of artesian well near Saline Landing.

	Feet.	Ins.
Soil and clay	25	...
Brown sand	1	...
White chalk	140	...
Blue marl	290	...
Sandy bed with pyrites		10
Bottom of well in sand at the depth of	457	...

The surface at the well is probably near the top of the chalk. A second well is located on the chalk, one-half mile north of the landing, near the edge of the bottom land. The chalk is exposed here in a low bench and has been quarried for local use in the interior work of buildings.

The third well is about three-fourths of a mile northeast of Saline Landing and is located upon the chalk 20 feet below the top of the formation. A record of this well, published by Dr. Branner, is as follows:

Record of artesian well three-fourths mile northeast of Saline Landing.

	Feet.	Ins.
Soil	1	...
White chalk	110	...
Blue marl	277	...
Sandy bed with pyrites		10
Sand in bottom of well at the depth of	388	...

If the record is correct the chalk at this place is nearly 120 feet thick.

It should be borne in mind that in wells which are bored by the drop drill, as in this case, it is not an easy matter to determine the parting line between two rock formations that are so closely alike in hardness, etc., as the chalk and chalky marl in question.

The chalk has been quarried for interior building purposes near the top of the formation in the northwest corner of the NE. ¼ of the SW. ¼ of sec. 30, T. 11 S., R. 27 W. Analysis No. 11, Table III (p. 735), is of fresh chalk in this quarry and shows it to be of nearly the same composition as that near the top of the chalk at Whitecliffs.

[a] Report cited above.

From the top of the chalk in this vicinity there is a gradual change upward through about 10 feet of marly chalk and then through nearly 30 feet of chalk-marl into the overlying blue clay-marl. The blue marl is continuous for 175 feet to the base of the Saratoga chalk-marl. The section is illustrated in fig. 64.

The middle portion of this chalk is exposed in the large mound which is surrounded by the bottom land of Plum Creek, in the center of the SE. ¼ of the SW. ¼ of sec. 21, T. 11 S., R. 27 W., on Mr. J. E. Johnson's place. Here also the chalk has been quarried for interior building purposes, giving fresh exposures of the rock. Analysis No. 12, Table III, is of fresh chalk taken from this quarry and is nearly the same as that of chalk taken from the quarry of the Whitecliffs Cement Works.

The lower sandy member of the chalk is freshly exposed in the head of the large drainage ditch near the middle of the west side of the SW. ¼ of the NW. ¼ of sec. 22, T. 11 S., R. 27 W. Analysis No. 14 of this chalk is practically the same as that of No. 6, which is of a specimen from the lower sandy member in the cliff at Whitecliffs Landing.

The upper and purer chalk member is well exposed in the ditches and chalk barrens on the lower ridge across the SW. ¼ of the NE. ¼ of sec. 22, T. 11 S., R. 27 W.

Nearly a full section of the chalk is exposed in the hill near the northeast corner of sec. 22, T. 11 S., R. 27 W., a part of the lower sandy member being concealed. A peculiar feature here of the exposed upper part of the lower sandy member is that it is indurated to a sandstone and contains inclusions or pellets of nearly pure white chalk. Upon weathering, the chalk disintegrates easily, forming porous cavities in the gray limy sandstone. It is probable that the weathering of the fossil shells which it contains aids in producing this honeycombed structure in the weathered rock.

This indurated sandy chalk is used locally for the construction of chimneys and foundations.

The easternmost exposure of the chalk, south of Plum Creek, is in the SE. ¼ of sec. 14, T. 11 S., R. 27 W. Here the chalk barrens in the slopes of the hill show the upper edge of the chalk and the succeeding chalk and clay marl for 50 feet above the creek bottom.

Chalk is said to be exposed in the branches of Plum Creek beneath the bottom lands farther east, probably in sec. 13, T. 11 S., R. 27 W.

Many other exposures, especially of the upper beds of this chalk, occur on the divides and low headlands which project toward Plum Creek bottom, between the small valleys.

CHALK-MARL OF THE WHITECLIFFS FORMATION NEAR OKOLONA.

In discussing the chalk of the Saline Landing district, it has been stated that the white chalk of the Whitecliffs formation is not known east of the source of Plum Creek, north of Columbus, because it is covered by deep soil and the bottom lands of Ozan Creek and Little Missouri River. The gradual thinning of the white chalk, by its change to chalky marl, from Saline Landing as far eastward as it could be traced, indicates that the formation, as a true chalk, would not continue probably beyond a distance of 20 miles.

One and one-half to 2 miles west of Okolona, and 30 miles east of the Saline Landing chalk area, the sandy, chalky marl, with its abundant fossil shells, *Gryphæa vesicularis* variety, is found. This is the same bed as that which occurs at the base of the bluff at Whitecliffs Landing, just below the Whitecliffs chalk. It is of the same nature and contains the same abundant fossil shell that is shown in Pl. L. Moreover, it occurs in the same relative position beneath the Saratoga chalk-marl.

This marl is perceptibly sandy, and its analysis, No. 20, Table III (p. 735), shows its highly siliceous nature.

Above this sandy marl is a bluish, very fine-textured, chalky marl that becomes less chalky upward, as do the same beds in the vicinity of Saline Landing. An analysis of specimens of these clay marls, occurring southwest of Okolona, nearly midway between the Whitecliffs sandy beds and the Saratoga chalk-marl, is given in No. 23. This analysis agrees closely with No. 13, which is that of the marl from the same relative stratigraphic position near Saline Landing. In each case the marl contains nearly 52 per cent of chalk.

The approximate outcrop of the chalky marl beds, which may be considered to be in the position of the Whitecliffs chalk, is shown in fig. 66.

With the thinning of the Whitecliffs chalk eastward, there appears to be a decrease in the thickness of the overlying marl. The blue marl, between the Whitecliffs chalk and the Saratoga marl opposite Saratoga, is about 200 feet thick, and that of the same formation at Okolona is probably not greater than 150 feet. The exposure of the chalky marl of the Whitecliffs formation at Okolona is terminated at the ends by the bottom lands of Antoine and Terre Noire Creeks.

The bearing or course of the Whitecliffs beds in this area is due to the combined effects of the structure of the rock and of the rugged surface of the land. The dip of the rock as in other parts of the region is toward the southeast at the low grade of about 50 feet per mile. If the land were level the outcrop would be in a straight band bearing in a northeasterly direction. As it is, the outcrop of the formation rises from the creek bottom level near the northeast corner of sec. 28, T. 9 S., R. 22 W., northward to the top of the ridge near the Okolona-Antoine road, and then bears eastward in the side of the northward-facing escarpment which extends from Okolona to Dobyville.

The formation is not known east of the Terre Noire because the surface of the country is generally occupied by post-Cretaceous deposits of gravel and sand.

Owing to the rugged surface of this chalk land in the vicinity of Okolona, the soil is generally thin and exposures of the fresh rock are very common, especially where the land has been long in cultivation.

Exposures.—At the Bonner place, 2 miles southwest of Okolona, the sandy fossiliferous marls are exposed in an old field. The freshly exposed rock is dull blue, massive, and but slightly indurated. It weathers in roughly conchoidal flakes and readily crumbles on exposure to the weather.

Good exposures may be seen on the place of Ky. Cargle, west of Okolona; also on the Jesse Carroll and Andy Joynes places, at the top of the ridge 2 miles northwest of the town.

The top of the sandy marl crops in the Okolona-Antoine road at Mrs. Tillman's house, 1½ miles west of Okolona.

The same rocks are exposed at the Ware graveyard, north of Okolona, and at many other places farther east in the northern slope of the escarpment.

SARATOGA[a] FORMATION.

The Saratoga chalk-marl, as explained in the general discussion of Upper Cretaceous rocks, occurs as a formation in the Upper Cretaceous nearly 200 feet above the true chalk and separated from it by marls of less chalky nature.

This formation has a maximum thickness of about 50 feet where complete sections have been found. The nature of the deposit varies only slightly from top to bottom, and there is but little change in character along its outcrop from the vicinity of Saratoga near West Saline River in Hempstead County to Little Deciper Creek near Arkadelphia in Clark County. The Saratoga marl is not known in this region west of West Saline River because of erosion and of concealment by Neocene gravel and sand in the highlands and by Pleistocene alluvium and silt in the lowland and river bottoms.

General section of the Saratoga chalk-marl, beginning at the base.

	Feet.
1. Chalky sandy marl, which contains great numbers of the fossil oyster *Gryphæa vesicularis*. These fossils are found in the marls some distance both above and below this formation, but in no other bed of rock in this region have they been found in such abundance. In natural exposures the chalk weathers from about them so that they usually almost cover the surface of the ground or are scattered in the soil. This shell bed at the base of the formation is such a marked feature that when it is once seen it may be easily recognized again. Some typical fossils from this bed are illustrated in Pls. LI and LII. This shell bed crops at the north border of the Saratoga marl and throughout its extent...............	3 to 5

[a] Name used by Dr. J. C. Branner in Cement materials of southwestern Arkansas: Trans. Am. Inst. Min. Eng., 1897.

FOSSIL SHELLS, GRYPHÆA VESICULARIS, FROM THE BASE OF THE SARATOGA CHALK-MARL.

1, Outside view of large valve; 1*a*, inside view of large valve. Natural size.

	Feet.
2. Generally even-textured chalky marl, which contains less sand than the beds higher in the formation. Chemical analyses of chalk from this bed show it to contain about 31 per cent of siliceous matter. The sand in this marl is perceptibly finer and the rock is more chalky in appearance than in other parts of the formation	10 to 15
3. Continuing upward from 2 the chalky rock becomes more sandy through imperceptible grades to limy greensand at the top of the formation. Analyses from the chalk near the central part of this member show it to contain from 40 to 50 per cent of silica	20 to 30

The Saratoga marl is a massive bed of dull-bluish, sandy, chalky rock. Exposures do not usually show distinct bedded structure, though a slight variation in weathered surfaces may indicate the direction of the dip of the rock. As the rock weathers it changes in color from dull blue to shades of grayish and creamy white. Its hardness and general physical appearance are almost identically the same as those of the lower sandy member of the Whitecliffs chalk. It breaks in rudely conchoidal flakes and crumbles at a tap of the hammer. Small pieces of the fresh rock may be broken by the hand and crumbled to dust between the fingers, but not without some difficulty.

WASHINGTON AREA.

Location and surface features.—Washington is located upon the greensand south of and stratigraphically above the Saratoga formation, and since the exposures of chalk along the railroad north of the town are typical and convenient to the only line of transportation across the area, the name of the town is most serviceable for reference.

The Saratoga chalk-marl crops in the highland near the divide facing the valleys of Plum and Ozan creeks. The two small streams which flow southward between Columbus and Saratoga cut through this marl and have concealed it by overwash of soil and sand in their immediate valleys. Many small branches which flow northward into Plum and Ozan creeks have their sources in or flow across the exposed surfaces of the Saratoga marl. Thus it is indented by small valleys, and since the rocks dip toward the southeast at a very low angle in a direction opposite to the flow of the streams, the outcrop of the formation, especially its lower and northern part, is very irregular. Generally there is an abrupt rise in the land from the top of the Saratoga marl at its south side into the succeeding greensand marl. This feature is especially marked east of the railroad, where the greensand rises above the chalk in an escarpment nearly 100 feet high. As a result of the steep grade at the top of the chalk, its upper contact or south side is a less deeply indented border than the north side.

The time required to traverse and accurately locate the very tortuous boundaries of the Saratoga chalk-marl was more than the writer had at his command. The limits of the formation on the map were located approximately, however, by means of section lines and subdivision surveys, as established by residents now owning the land. The area as mapped includes practically all the Saratoga marl, together with some of the clay-marl below where it outcrops in the small cross valleys.

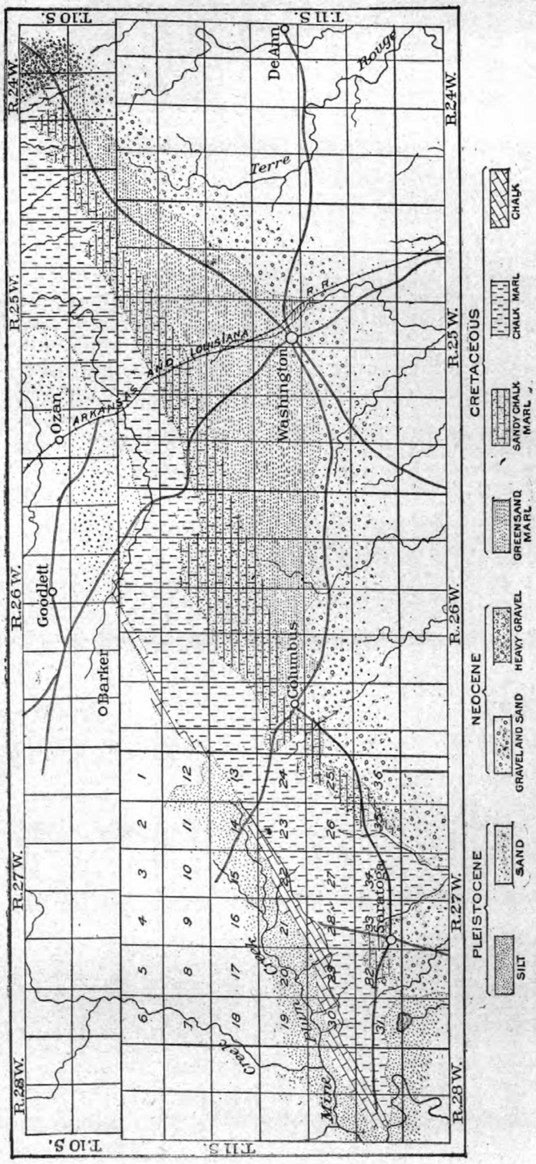
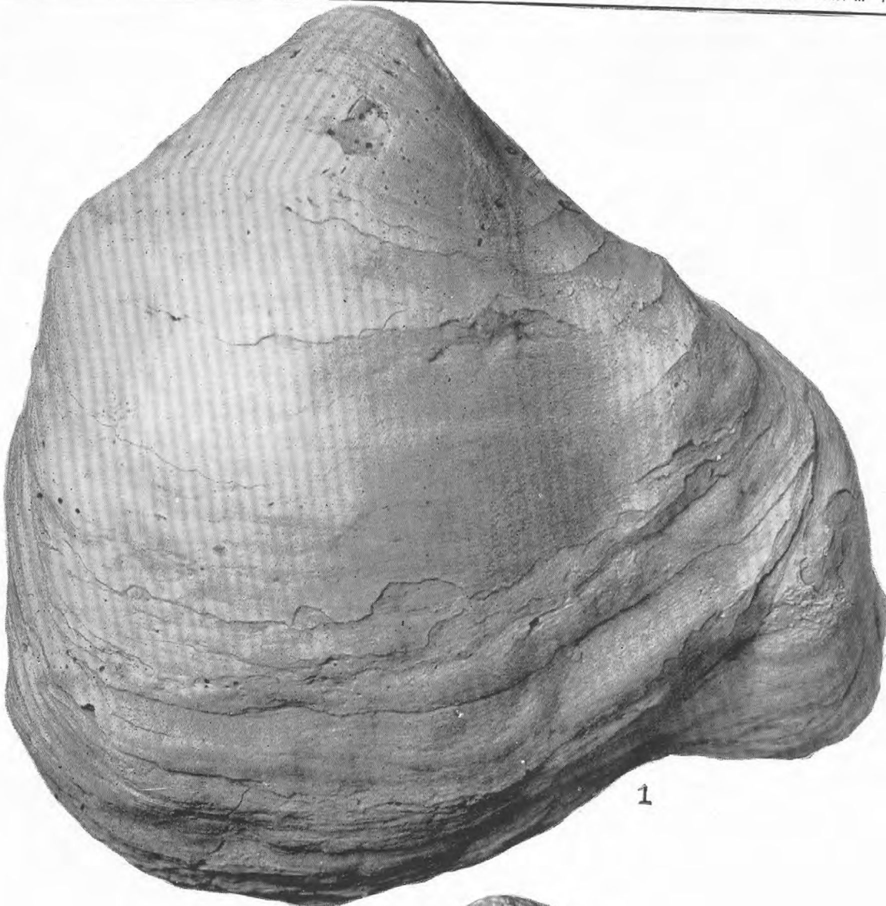


FIG. 63.—Map of the Washington area.

Description of the rock.—The rock section from the Saratoga chalk-marl down to the Whitecliffs chalk of the Saline Landing area is well exposed, as illustrated in section of fig. 64.



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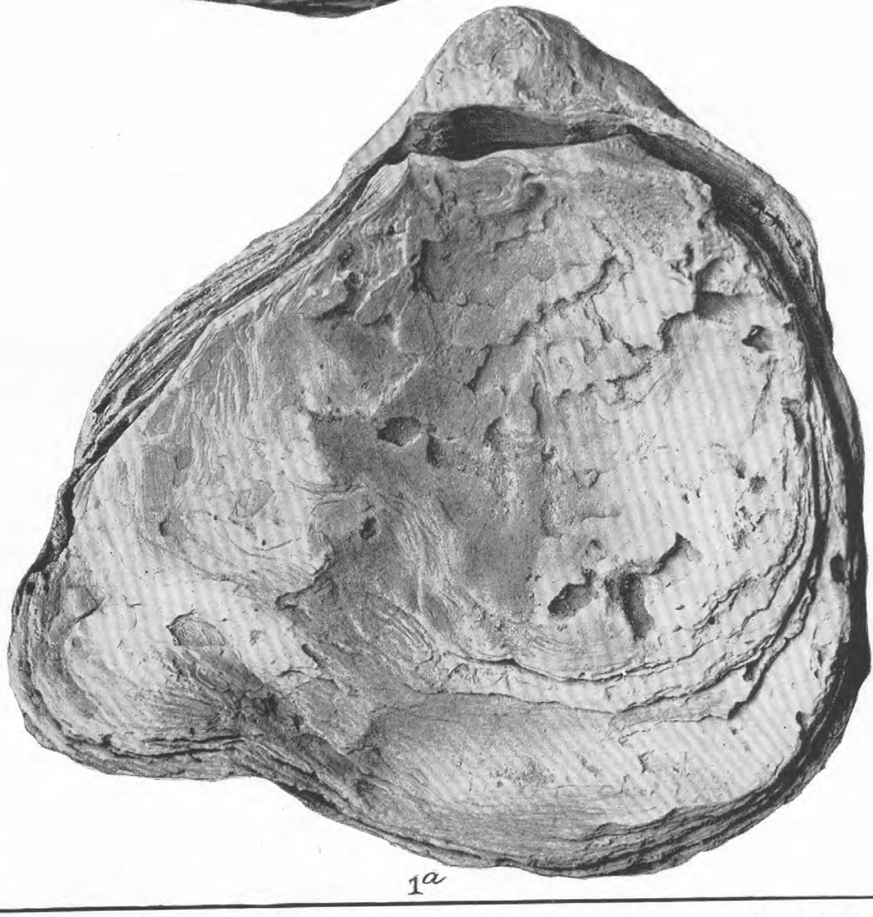


1a

FOSSIL SHELLS, GRYPHÆA VESICULARIS, FROM THE BASE OF THE SARATOGA CHALK-MARL.

1, Outside view of large valve; 1a, reverse of 1, showing large and small valves together.

Section north of Saratoga (see fig. 64).

	Feet.
1. From the level of Saratoga down to Saratoga marl, surficial deposit of fine yellow sand, about	40
2. Saratoga marl exposed in brink of hill north and east of Saratoga and in knob one-half mile north of Saratoga, lower beds of the formation	20
3. Limy blue clay marl	175
This marl is exposed around the base of the hill at Saratoga, and in the cultivated lands 1½ miles north of the town it becomes gradually more chalky downward from the top to its contact with the chalk-marl below.	
4. Bluish friable chalk-marl	20 to 30
This is the gradation bed from the blue marl above into the purer chalk below.	
5. White chalk in the Saline Landing area	

Chalk-marl exposures.—Thick deposits of loose yellow sand cap the hill at Saratoga, replacing or concealing all of the Saratoga chalk rock, except the lower beds in the slopes east and northeast of the town. On the road from Saratoga to Saline Landing the traveler passes from the surficial sand to the clay-marl below without encountering the Saratoga formation.

The Saratoga chalk has been removed by erosion from the wide valley between Saratoga Hill and Mr. Thomas L. Jones's place in the

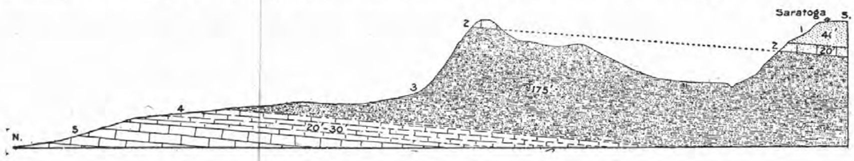


FIG. 64.—Profile section of chalk and marl, north from Saratoga (see section above).

NE. ¼ of sec. 35, T. 11 S., R. 27 W. The chalk rock should crop in the sides of the valley, gradually descending southward to the bed of the stream, about 1½ miles south of the Columbus-Saratoga road, but it seems to be concealed by the loose sand.

The lower part of the Saratoga chalk crops out in a considerable area on Mr. Jones's place in the NE. ¼ of sec. 35, the SW. ¼ of sec. 25, and the SW. ¼ of sec. 36, T. 11 S., R. 27 W. The chalky oyster-shell bed at the base of the formation is well exposed north, south, and west of the house, which is in the NE. ¼ of the NE. ¼ of sec. 35. Two specimens of the rock furnished by Mr. Jones were examined by Dr. Branner, and analyses were made to determine their quality.[a]

The localities of these specimens were visited with Mr. Jones by the writer, and samples of the chalk were collected from beneath the soil. These samples and those submitted to Dr. Branner were taken from the top of the oyster-shell bed near the base of the formation, and are not physically different from the rock occurring in the same bed examined at numerous other localities in this area. The fresh rock is grayish white and perceptibly sandy.

[a] Cement materials of southwest Arkansas.

The chalk-marl and succeeding sand contact extends east and west about one-fourth mile south of Mr. Jones's house, and then bears northward, crossing the road about one-half mile farther east. This surficial sand, resting upon the chalk, covers the high country between Mr. Jones's place and Columbus, in which no exposures of the chalk were observed. The outcrop of the lower beds, however, extends around north of the sand belt in cultivated fields toward Columbus.

The *Gryphæa vesicularis* shell bed at the base of the formation is exposed at the edge of the highland near the Columbus-Albrook road, 1 mile northwest of Columbus. The same bed is exposed also at the crest of the highland 1 mile north of the town. This fossil, characteristically abundant at the base of the Saratoga chalk-marl, is illustrated, natural size, in Pls. LI and LII. The chalk-marl highest in the formation occurs in the cultivated fields between the outcrop of the shell bed and the town.

From the vicinity of Columbus eastward to the end of the formation in the Washington area the whole of the Saratoga formation crops out or is covered only lightly by soil. Throughout this extent the basal shell-bed member of the chalk-marl is almost continuously exposed,

FIG. 65.—Section of chalk-marl along the railroad north of Washington, Ark.

except in the immediate bases of the valleys, and may be easily located through the open fields by means of the abundant shells weathering upon the surface. This bed is harder than the underlying clay marls and crops out near the heads of ditches and low breaks which descend to the more level "black land" bordering the creek valleys. Above the tops of these breaks the upper part of the Saratoga marl occurs in more level land, which, where a covering of soil occurs, is occupied by cultivated fields.

Between Columbus and the railroad north of Washington the chalky marl was not found to crop out more than 30 feet in thickness, and usually 10 to 20 feet of the lower part was all that could be found exposed.

The overlying greensand marl is more friable than the Saratoga chalk-marls, and its soil descends and conceals the contact between the two as well as the upper part of the latter. A section of the Saratoga marl with better exposures than are usually to be found occurs along the railroad north of Washington. This railroad passes up the side of the small valley almost directly across the formation, and the railroad cuts, as well as the near-by ditches descending into the valley, give fresh exposures of the chalk.

The north cut on the railroad is in a blue clay-marl 30 to 50 feet below the base of the Saratoga formation. It is 10 feet deep and about 300 feet long. The marl in this cut, which was originally blue, is weathered a creamy yellow to a depth of about 8 feet. It is transected by many joints, which pass nearly vertically across the bedding and continue down below the base of the cut. Along these joints, even below the zone of general weathering, the blue color of the marl is changed to yellow for a distance of several inches.

Analysis No. 15, Table III, p. 735, is of the unchanged blue marl from the base of the cut, 10 feet below the soil. The fresh marl is friable when dry and plastic when wet. It has a very fine texture and contains scarcely perceptible grit, yet the analysis shows it to contain 43 per cent of silica and 6.5 per cent of clay. Nearly 40 per cent of this silica is in the form of impalpable sand.

The *Gryphæa vesicularis* shell bed, the base of the Saratoga formation, is exposed in the field southwest of this railroad cut. The middle cut is one-third of a mile south of the north cut and is in the lower part of the Saratoga chalk above the oyster-shell bed. This cut is 300 feet long and but few feet deep, exposing an estimated thickness of 15 feet of rock. The structure of the rock indicates a low inclination toward the south, but is not sufficiently clear to determine the degree of dip. Ditches above the south end of the cut expose about 25 feet of chalk marl above that at the railroad, making the whole section of rock exposed at this place nearly 40 feet. Very little change in the nature of the rock could be noted in this section.

Analysis No. 16, Table III, is of the fresh chalk rock near the center of the middle cut, from the lower and more chalky part of the formation, and shows that this marl contains less than one-half the amount of silica found in the blue marl 40 feet below, though in physical appearance it is more sandy.

One-half mile south of the middle cut and a few hundred feet north of the south cut the top of the Saratoga marl is exposed in a ditch at the railroad. The sandy marl in this exposure is but little above the chalky marl at the top of the exposure opposite the middle cut. It is massive, dull blue, and very sandy, approaching a sandstone in composition.

The south cut, which is about 2 miles north of the town of Washington, is in the lower part of the greensand marl which overlies the Saratoga formation. This cut is about 30 feet in depth and about 300 feet long. From the surface downward about 20 feet the greensand is weathered from dark blue or greenish blue to shades of dull brownish yellow. Unaltered marl was collected from near the base of the cut, and its composition is shown in analysis No. 17, Table III. Physically it is very sandy, and the analysis shows that it contains 75.77 per cent of silica and 5.72 per cent of lime. Similar greensand marl occurs between this cut and Washington, and its thickness is estimated to be more than 100 feet.

From the railroad eastward to the end of the formation in this area, in sec. 29, T. 10 S., R. 24 W., the Saratoga chalk crops in an irregular belt one-half to three-fourths mile wide, making an intermediate upland, marked by projecting ridges and spurs between the high timbered greensand country on the south and the flat black land of the clay marls bordering Ozan Creek bottom on the north.

When this country was settled, more than fifty years ago, the soil of the Saratoga marl area was most desired because of its fertility and position on the upland. As a result the forest was cleared and the soil was exposed to subaërial agents of erosion. During the cultivation of this land much soil has been removed by erosion, and steep-sloping gullies render much of the area worthless.

OKOLONA AREA.

Location and surface features.—This area is in the southwestern part of Clark County, south and east of Okolona, between the bottom lands of Antoine and Terre Noire creeks.

As in the Washington area, the Saratoga marl in the vicinity of Okolona was located approximately by reference to sections and subdivision surveys established by landowners. The Saratoga chalky beds at the crest of the ridge south of Okolona are 50 to 150 feet above the lowland to the west and south. The crest of this ridge slopes southward with the dip of the rock, which is nearly 50 feet per mile.

East of Okolona the chalky marl forms a triangular area of rolling upland about 3 square miles in extent.

The stream which rises in the southwest part of the town and flows southeastward past the railroad station separates the area south of the town from that east of it. It is probable that the two areas in question are connected by narrow bands of outcropping marl which extend down the sides of the valley about 2 miles southeast of the village.

Neocene deposits of gravel and sand overlie the Saratoga formation about 2 miles east of Okolona and almost completely conceal it, beginning near the west side of sec. 30, T. 8 S., R. 21 W., and extending eastward to the Terre Noire Valley. This gravel and sand make a highland from the crest of the escarpment southward.

Below these deposits the Saratoga chalk-marl is partially exposed near the crest of the escarpment north of the Okolona-Dobyville road, from the east side of sec. 30, T. 8 S., R. 21 W., to the edge of the Terre Noire bottom, 1½ miles east of Dobyville.

Exposures.—The Saratoga marl, near the middle of the formation, is well exposed toward the top of the ridge at the forks of the road, 1½ miles south of Okolona. In physical appearance this rock is the same as that at the middle of the formation in the vicinity of Washington. It is massive and dull blue on fresh exposure and weathers to shades of drab or light yellow. Analysis No. 19, Table III, page 735, shows

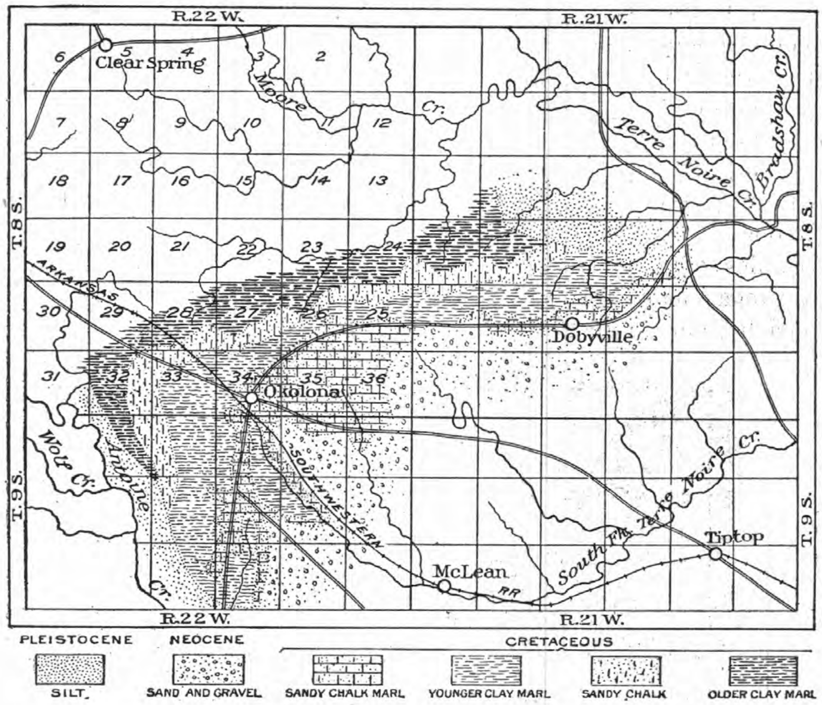


FIG. 66.—Map of the Okolona area.

the chalk-marl in this locality to contain nearly 43 per cent of silica and 49 per cent of calcium carbonate.

Two and one-half miles south of Okolona and one-fourth of a mile west of the road, on the Mat Hardin place, deep gullies expose the

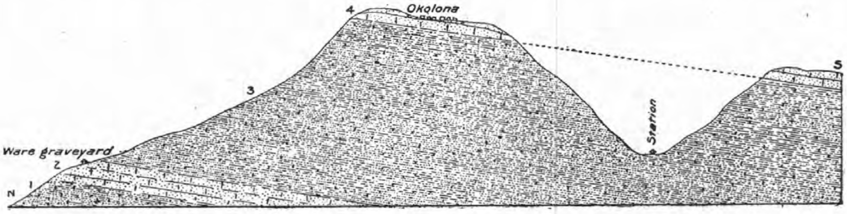


FIG. 67.—Section of chalk-marl at Okolona.

1, blue marl below Whitecliff formation; 2, sandy chalk-marl at base of Whitecliff formation; 3, blue chalky marl; 4, Saratoga chalk-marl.

lower 20 feet of the Saratoga marl as well as the blue marl below. The *Gryphæa vesicularis* bed is well marked, but the fossils are a little less abundant than in the Washington area, 20 miles farther west. In the lower 10 feet of the formation the chalk-marl is finer in texture and more chalky than in the higher beds. The result of an analysis of chalk from this place is given as No. 21, page 735, and shows that the amount of silica is nearly 10 per cent less than in the marl near the middle of the formation.

Numerous other exposures of the lower part of the formation occur in the gullies and slopes of the hill on the west side of the ridge, where the land was once cultivated. The top of the Saratoga marl passes beneath the bottom land of Little Missouri River, about 3 miles south of Okolona.

Five miles south of Okolona the greensand marl, which belongs above the Saratoga chalk, forms the bluffs from the level of the Little Missouri bottom up to the top of the ridge. This is the greensand

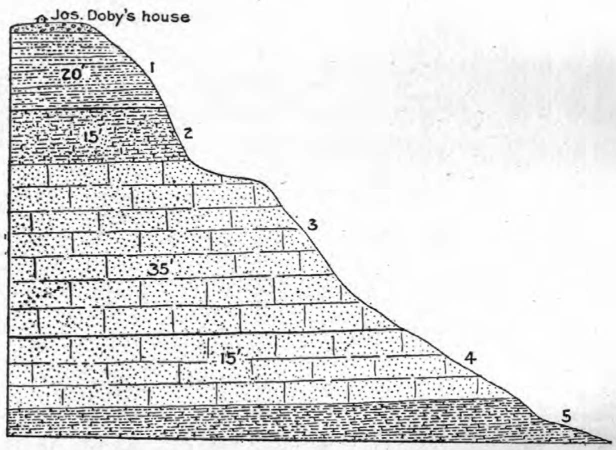


FIG. 68.—Section of chalk-marl at Dobyville (see section on page 723).

formation which occurs between Washington and the Saratoga chalk in Hempstead County.

About 20 feet of the middle portion of the formation is exposed in the Okolona-Garden road, 1 mile east of Okolona.

In the high rolling country east of Okolona the Saratoga chalk-marl is generally concealed beneath its own soil or beneath sand of Neocene age.

The lower beds of the chalk outcrop in the Okolona-Dobyville road, 2 miles west of Dobyville, and at several other places in the top of the escarpment between Okolona and Dobyville.

One-fourth of a mile north of Joseph Doby's house at Dobyville, the full section of the Saratoga chalk-marl is exposed in an old field.

An artesian well was drilled at Doby's house on the top of the hill in 1892, but no record was kept below the 20 feet of gravel and clay forming the crest of the ridge. Following is a section of Saratoga chalk-marl at Dobyville:

Section at Dobyville (see fig. 68).

	Feet.
1. Gravel, reddish and yellow stratified clays	20
2. Blue marl	15
3. Dull-bluish chalky marl	35
This marl is slightly indurated at the top and contains numerous casts of bivalve shells and gastropods. It is a calcareous sandstone at the top. The beds become more chalky downward until the lower part the chalky marl is found to be the same in nature as that described as occurring south of Okolona and in the Washington area.	
4. Even-textured chalk-marl, with *Gryphæa vesicularis* shells at the base	15
This member contains more chalk than those above and has finer texture. In places, also, very fine particles of greensand were noted disseminated through the marl.	
5. Fine-textured blue clay marl	
This is the upper part of the 150 to 200 feet of blue marl which lies between the Whitecliffs chalk formation and the Saratoga chalk-marl.	

From the vicinity of Okolona eastward, the outcrop of the Saratoga marl descends gradually from the brink of the escarpment to the level of the river bottom, nearly 2 miles east of Dobyville.

DECIPER AREA.

The next known occurrence of the Saratoga chalk-marl east of

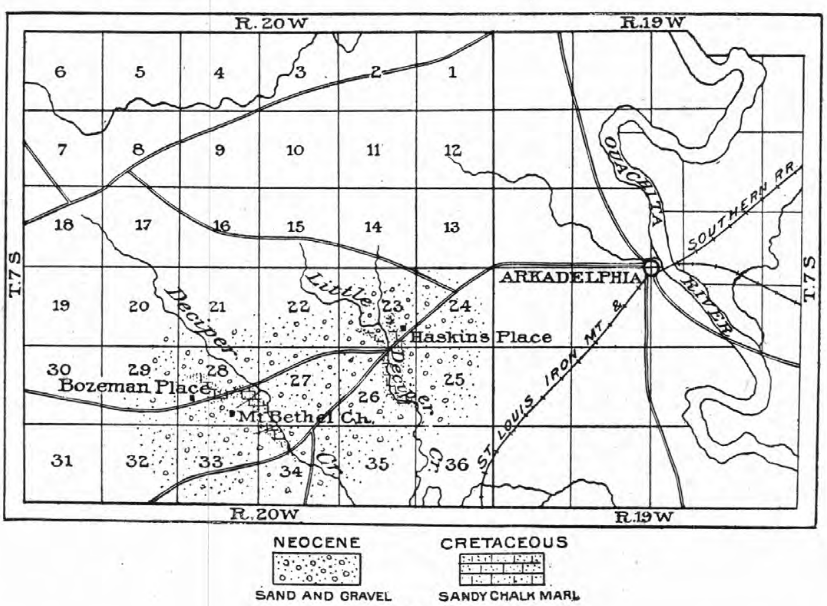


FIG. 69.—Map of the Deciper area.

Okolona is on the Big Deciper and Little Deciper creeks, 3 to 5 miles west of Arkadelphia. The Okolona and Deciper areas are separated by the flat sand and silt deposits of the Terre Noire and the higher broken gravelly land between the valleys of the Terre Noire and Deciper Creek.

The occurrence of the Saratoga chalk on the Deciper creeks is confined to outcrops in the middle and lower slopes of the valley near the Arkadelphia-Dobyville and Arkadelphia-Hollywood roads. The general location of the outcrop is shown in fig. 69.

The chalk-marls are overlain by thick deposits which, in the lower part, are composed of friable yellow sand interbedded with tough blue clay. Where contact exposures could be found these interstratified sands and clays are overlain by surficial deposits of yellow sand and coarse gravel.

From the level-topped ridges near the valleys, deep short gulches descend steeply to the creek valleys. The chalk-marls are exposed frequently in these gulches, occasionally on the spurs between them, and rarely in the valleys of the main creeks.

Exposures on Big Deciper Creek.—Near the center of sec. 28, T. 7 S., R. 20 W., on the Bozeman place, one-third of a mile northeast of the house, about 30 feet of the Saratoga chalk-marl is exposed from the base upward.

Section of the Saratoga chalk-marl at the Bozeman place, beginning at the base.

	Feet.
1. The blue marl from the *Gryphæa vesicularis* shell bed downward, exposed..	15
2. *Gryphæa vesicularis* shell marl	1–2
The limits of this shell bed are not sharply marked. Through 1 to 2 feet of the marl at the base the shells are abundant, and in it is a thin layer of shells indurated by calcareous matrix	
3. Even-textured blue chalk-marl	15
This chalk contains a sprinkling of fine greensand, and in all respects is the same as the lower 15 feet of the formation at Dobyville and Okolona. Analysis No. 24, Table III, shows this marl to contain about 30 per cent of sand and 61 per cent of chalk.	
4. Chalky marl, more sandy than that of 3	10–15
The sandy element in this marl increases in quantity upward.	
5. Overwashed, sandy soil to the top of the ridge.	

At the two points, one-fifth of a mile northeast, and 500 feet east of the Bozeman house, the chalky marls shown are higher in the formation and still more sandy than that of No. 4 in the section above. These outcrops are in the heads of narrow gulches which descend to the Deciper Valley. At the locality 500 feet east of the house the marl is very sandy, partially indurated, and contains numerous casts of fossils similar to those found near the top of the formation at Dobyville. The exposures here show about 10 feet of marl and are just below the springs which flow from the base of the stratified yellow sands and blue clays.

About 10 feet of interstratified sand and clay is exposed above the sandy marl, and then follows an overwashed yellow sandy soil to the top of the hill 40 feet above.

One-fourth of a mile southeast of Mount Bethel Church, near the northeast corner of sec. 33, T. 7 S., R. 20 W., beds similar to those east of the Bozeman house are exposed. Here a spring issues from the contact between the chalk-marl and the overlying sand and blue clay. The top of the marl is 70 feet below the crest of the hill. A bed of blue clay, having the consistency of putty and being very tough, projects as a ledge in the friable yellow sand above the marls, while thin laminæ of similar clay are contained in the yellow sand itself.

In the Arkadelphia-Okolona road, on the west bank of Big Deciper Creek, near the middle of sec. 34, T. 7 S., R. 20 W., the chalky sand of the upper part of the Saratoga formation is exposed, as well as in the bluff of the creek near by. The top of the sandy marl, which stands here 20 feet above the creek, contains casts of fossils as at the Bozeman place, and is overlain also by the same kind of interstratified sand and clay.

No fossils were seen in the beds above the chalk-marl, and they are distinctly unlike any strata in this region known by the writer to be of Cretaceous age.

Exposures on Little Deciper Creek.—Twenty feet of the even-textured lower and more chalky member of the Saratoga chalk-marl is exposed in the road cut on the Arkadelphia-Okolona road, 100 yards west of the Little Deciper Creek.

Overwashed gravel, sand, and clay conceal the higher beds of the chalk-marl. The *Gryphæa vesicularis* bed with underlying blue marl crops a few feet above the creek bottom.

One-half mile above the road, on the Wright place, the lower 30 feet of the Saratoga formation is exposed in the gullies at the west side of of the creek bottom. The lower 10 to 15 feet of the marl is identically the same as that found at the road and on the Bozeman place west of Big Deciper Creek, as shown in analysis 26, Table III. The basal member of the chalk-marl containing the same indurated shell bed outcrops here at about 10 feet above the creek bottom, and below it is the blue marl. Yellow sandy clays overlie the chalky marl here as in the exposures noted on Big Deciper Creek.

At the east side of the creek bottom on the Arkadelphia-Okolona road, and northward through the Haskins place, the lower part of the chalk-marl is exposed in ditches and gullies washed in an abandoned field.

ECONOMIC GEOLOGY.

GENERAL STATEMENT.

The purpose of the following brief notes on the nature of hydraulic cements is to place an estimate upon the relative values of the chalk and marl of southwestern Arkansas as cement materials.[a]

Common lime, generally known as quicklime, is calcium oxide (CaO), and is commercially produced by expelling carbon dioxide (CO_2) from lime carbonate ($CaCO_3$), which occurs as limestone, marble, or chalk, by the application of a high degree of heat.

Quicklime has an active chemical affinity for water, and when brought into contact they will rapidly combine, with the production of considerable heat. The lime increases in volume and slacks to a very fine powder. Should the lime when calcined contain about one tenth of its volume of clay, it will slack slowly upon the application of water, producing a slightly hydraulic lime. Where properly mixed with sand and water it will set, making a mortar of high grade. In case the lime rock contains 18 to 20 per cent of clay in combination, it will make a high-grade or eminently hydraulic lime. Such limes will not slack upon being calcined, but require to be reduced to powder in order to be of use. Eminently hydraulic lime of this grade has been used extensively as natural cements.

NATURAL HYDRAULIC CEMENT.

Natural hydraulic cement is made by burning a lime rock which contains lime, silica, alumina, besides magnesia, iron, alkalies, etc., varying in quantity within tolerably wide limits.

The proportion of clay (silicate of alumina) combined with the lime in natural cement, it is claimed, should be 35 to 40 per cent. Analyses of some of the best grades of natural cement are shown in Table I, page 727.

The rock is quarried, broken, and burned in a manner similar to that used in the manufacture of lime, but the burning is carried to higher temperatures. The burned material is ground to fine powder—the finished product—which, when properly mixed with water, will set, making a rock of stony hardness, and will endure for a long period either in air or water. It must be true, however, that a natural cement would ordinarily contain inert an excess of one or more of the substances used in its production, since the true combining proportions of a hydraulic cement can vary only within narrow limits.

An enormous quantity of natural cement is produced annually and used in all kinds of construction where hydraulic cement is in demand.

[a] The following American works on cements are the principal ones to which reference has been made in the preparation of these notes: Q. A. Gillmore, Limes, Hydraulic Cements and Mortars (1888); F. P. Spalding, Hydraulic Cement, its Properties, Testing and Use (1897); Uriah Cummings, American Cements (Rogers and Morrison, Boston, 1898); Addison Clarke, Architects' Hand Book on Cements (Wm. Wirt Clarke & Son, Baltimore, 1899).

TABLE I.—*Analyses of hydraulic limes and natural cements.*

No.	Silica.	Alumina.	Iron oxide.	Lime.	Magnesia.	Carbonic acid, water, and loss.	Alkalies.
1	24.33	1.92	....	71.91	....	....	....
2	29.71	5.35	3.29	59.53	0.95	....	....
3	28.39	11.71	2.29	43.97	2.21	2.44	9.00
4	26.69	7.21	1.30	43.12	19.55	1.00	1.13
5	30.00	11.00	1.50	34.00	16.00	....	....

1. Hydraulic lime, Lyme Regis, England. Used in the construction of London docks.
2. Eminently hydraulic lime, Hollywell, Wales. Used in the construction of the Liverpool docks.
3. Cumberland hydraulic (natural) cement, Cumberland, Md.
4. Akron hydraulic (natural) cement, "Cummings," Akron, N. Y.
5. Average natural cement.[a]

PORTLAND CEMENT.

GENERAL STATEMENT.

Natural rock is rarely found which contains, evenly distributed, the proper proportions of lime and clay, or lime and finely divided silica, which will produce a high-grade Portland cement. The usual Portland cement, therefore, is an artificial product made by burning to semifusion an intimate mixture of materials containing lime, silica, and alumina in proportions which are, within certain narrow limits, fixed and definite, and crushing finely the resultant "clinker." Four points must therefore be considered to be of cardinal importance in the manufacture of Portland cement:

(*a*) The cement mixture must be of the proper chemical composition.

(*b*) The materials of which it is composed must be finely ground and intimately mixed before burning.

(*c*) The burning must be conducted at the proper temperature.

(*d*) After burning, the clinker must be finely ground.

It will be seen that the last three fall properly under the head of processes of manufacture, which can not be discussed at length in the present paper. They are accordingly treated briefly in the section on processes of manufacture (p. 729). The first requirement is, however, of interest in connection with economic geology, and will therefore be discussed at some length in the following pages.

THE MATERIALS.

While chemical analyses of various good brands of Portland cements differ somewhat in the proportions of the various components shown, this variation will be found to be within quite narrow limits, at least

[a] From Architects' Hand Book on Cements.

so far as the more important constituents are concerned. The following analyses are of type brands of Portland cement produced in America and Europe:

TABLE II.—*Analyses of Portland cements.*

No.	Silica.	Alumina.	Iron oxide.	Lime.	Magnesia.	Carbonic acid, water, and loss.	Alkalies.
1	20.42	12.00	1.87	63.13	0.58	2.00	....
2	23.36	8.07	4.83	59.93	1.00	2.16	0.50
3	20.80	7.39	2.61	64.00	....	5.20	....
4	22.74	7.74	3.21	56.68	.57	6.24	.63
5	21.11	11.30	3.36	58.03	2.93	2.05	.71
6	22.00	8.00	3.00	62.00	2.00	....	....

1. Natural Portland cement. Boulogne, France.
2. American Portland cement. "Grant," Egypt, Pa.
3. American Portland cement. "Empire," Warren, N. Y.
4. English Portland cement. Given by Reid as first quality.
5. German Portland cement. Given by Reid as first quality.
6. Average Portland cement. Given by Architects' Hand Book on Cements, cited.

Theoretically a large number of materials might be made use of in the manufacture of Portland cement. Economic considerations, however, restrict the choice to such an extent that in practice only the following materials need be considered.

Two general classes exist:

(*a*) Argillo-siliceous limestones occur, containing the various necessary elements in nearly the proportions to give, after burning, a Portland cement. If the composition of this natural limestone be exactly right, as in the Boulogne (France) deposits, no admixture of other material is required. In Pennsylvania there are deposits of natural "cement rock" which runs somewhat too low in lime and therefore requires the addition, before burning, of a small amount of a purer limestone. The analyses of some of the chalk deposits of southwestern Arkansas, as shown in the pages below, indicate that they approach very near to a natural Portland cement rock. There are other chalks in the same vicinity which contain a large excess of lime, while other deposits contain an excess of silica and alumina in a very finely divided state. It would appear, therefore, reasonable that these chalky materials which occur in associated localities could be economically combined to produce Portland cement. Aside from the works of Pennsylvania, in the Lehigh Valley, and of the adjoining parts of New Jersey, however, almost all of the Portland cement manufactories of the United States belong to the second class, in which—

(*b*) The silica and alumina are obtained from one material, the lime from another. In this case clay or shale is the material commonly used to furnish the necessary amounts of silica and alumina. It should be noted that the silica must occur in combination with alumina as silicate of alumina or in a very finely divided state. As it is economically impossible to separate the sand from a sandy clay, care must be taken to select a clay deposit free from such impurities. Organic matter is of little importance, as it burns out during firing.

Experts on the nature of cements are divided in opinion concerning the chemical reactions produced in burning lime and clay together at the high temperatures used in the manufacture of Portland cement. It is generally considered, however, that the essential reaction in the production of Portland cement is in the combining of silica and lime, producing silicate of lime. The part taken by the alumina of the clay is a matter of varied opinion. It is believed by able chemists that it acts as a flux in aiding the combination of silica and lime and probably combines, in part at least, with them.[a]

Oxide of iron is believed to have an influence in the fusion of the lime and silica similar to that exerted by alumina. Iron is the usual coloring agent in Portland cement, giving it shades of yellowish to dark greenish drab, which coloring depends upon the amount of the iron constituent, and the extent of burning.

The alkalies, potash and soda, in small quantities, are considered to have a beneficial effect as flux in the production of hydraulic cements.

That magnesia occurring in cement material as carbonate of magnesia acts in a way similar to that of carbonate of lime during calcination in the progress of cement manufacture is claimed by some leading authorities, and that it is a strong agent in any cement as long as it is not in excess of its true combining proportion with the silica and alumina present. Other authors of equal prominence assert that when calcined at low temperatures it is active settling, but when present in Portland cement, which is burned at very high temperatures, it is slow of hydration, and on this account will reduce the quality of the cement. Others claim that both magnesia and alumina are inert substances in a cement.

The manufacturers of Portland cement will not admit more than 3 per cent magnesia in their product, while those producing natural cement admit 15 to 18 per cent magnesia in their best grades.

PROCESSES OF MANUFACTURE.

The following procedures are necessary in the manufacture of Portland cement:

1. Preparing and grinding the materials.
2. Mixing the materials.
3. Burning the mixture to clinker.
4. Grinding the clinker.

[a] J. S. Newberry, Mineral Resources of the United States, 1892.

(1) The methods of preparing and grinding will depend upon the nature of the materials. If the material is natural cement rock and hard, it is required to be reduced in a crusher and then ground in emery or other mills that will reduce it to fine powder. If the material is chalk or marl, as that occurring in the Arkansas region, similar mills will be required in grinding, but with greater economy and less time. The clay is dried in open air, over steam coils, or by other artificial dryers, and then ground in emery mills, as is the crushed limestone, or passed through a disintegrator.

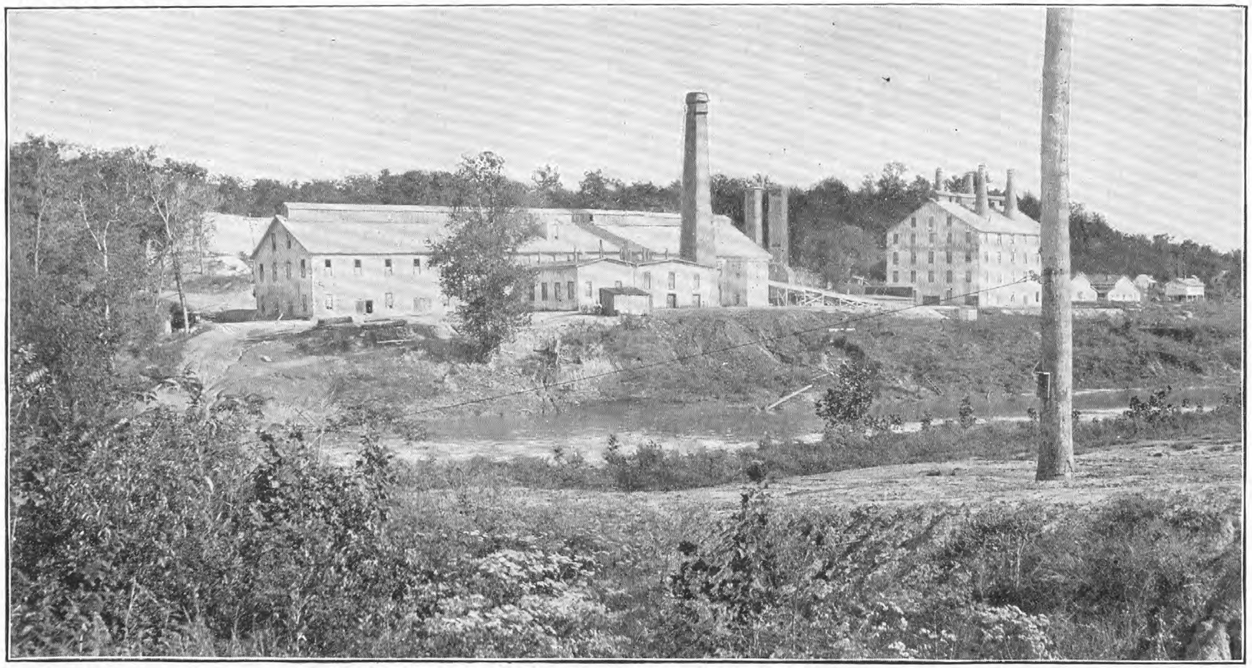
(2) After being thus finely ground separately, the materials are weighed and mixed thoroughly by either the dry or wet processes. In the dry process the mixing usually occurs before the final stage of reduction. This process is considered most economical when the material is formed into bricks and the dome or shaft kiln is utilized in burning. In the wet process the finely divided material is mixed in series of pans or vats, when it is still further reduced. The wet process is used when rotary kilns are employed. In this case the mud or "slurry" is sent in a semifluid condition to the kiln, where it is resolved into pellets in the process of burning. By whatever method the materials are mixed, it is necessary to so intimately associate the particles of lime and clay in the proper proportions that when burned they will chemically combine without an excess of either remaining.

The kilns can not be described here in detail in the space allowed. The dome kiln is practically only a slightly modified limekiln, while shaft and rotary kilns are too complicated to be described briefly.

(3) In the process of burning, the heat should be applied gradually, so that the moisture is completely removed before the carbonic acid is expelled. This demands perfect control of apparatus in increasing and regulating the heat. Gradual increase of the heat is continued until the proper stage of vitrification of the material is reached, producing a clinker.

The texture rather than the color of clinker generally indicates its quality, for the shade of color depends upon the quantity of iron contained. There is a change in color of any cement material in the progress of burning, and the color of the clinker producing the best cement in each case will be determined by experiment.

(4) After burning the clinker, if in large lumps produced by dome and shaft kilns, it is first reduced in crushers to proper sizes for grinding. The next reduction is accomplished in modern plants in ball mills, and the final stage in tube mills. In some cases, however, emery mills are used in place of the ball and tube mills. The clinker produced by rotary kilns, not being in large pieces, does not require crushing, but can be sent direct to the mills. By whatever means the clinker is ground, it is essential that the final product be reduced to the finest powder.



PORTLAND CEMENT WORKS AT WHITECLIFFS LANDING.

TESTS OF THE PRODUCT.

The first requisite of a Portland cement is that it shall not contain free lime, which will cause it to expand and crack after the addition of water in making the mortar. To overcome this defect, air is permitted to have access to the fresh cement in order that the free lime may be hydrated and slacked before the cement is used.

The fineness of a cement is determined by the percentage which passes standard sieves. The three following forms of sieves are generally adopted for use in testing fineness:

No. 50 (2,500 meshes per square inch), No. 35 Stubbs's wire gage.
No. 74 (5,476 meshes per square inch), No. 37 Stubbs's wire gage.
No. 100 (10,000 meshes per square inch), No. 40 Stubbs's wire gage.

The fineness of cements demanded in the market is variable, depending upon the requirement of use and upon the engineer submitting the specifications. In public works the usual demand is that 90 per cent shall pass the No. 50 sieve of 2,500 meshes per square inch.

Requirements vary, also, as to the time of the initial setting of standard Portland cement, depending on the use to which it is applied. Cement to be used in water must be quick setting. The average high-grade Portland cement, when properly mixed, should set sufficiently to bear light pressure of the thumb nail in about thirty minutes. The time of initial setting, however, is not an index of the strength or durability of the cement. The last test usually applied is that for strength and is generally performed by the purchaser, as well as the maker, especially when large quantity is demanded.

The tests to determine strength are tensile, compressive, transverse, and shearing. Of these the tensile test only is usually applied in determining the fitness for commercial cement. The cement is prepared for testing either neat—i. e., without sand, or with sand. In the first case the cement is mixed rapidly and thoroughly with approximately 25 per cent of water, molded in 8-shaped form, and allowed to remain in air for one day. It is then immersed in water and at a specified day or week is tested for tensile breaking strength in pounds per square inch of broken section. In the second case sand is thoroughly mixed with the cement dry, in parts of 1 to 1 or 3 to 1, and then mixed rapidly with 15 per cent or 12 per cent, respectively, of water. The breaking test is performed as in the first case.

Following is the tensile strength which has been required in standard specifications for good Portland cement:

Neat: One day in air and six days in water, approximately 350 pounds per square inch.

One sand to one cement: One day in air and six days in water, approximately 200 pounds per square inch.

Three sand to one cement: One day in air and six days in water, approximately 75 pounds per square inch.

CHALKS AND CLAYS OF SOUTHWESTERN ARKANSAS AS PORTLAND CEMENT MATERIALS.

ECONOMIC NOTES ON THE CHALKS AND MARLS.

Chalk of the Rocky Comfort area.—Analyses Nos. 1, 3, and 4 of Table III (p. 735) are of the average quality of white chalk in the vicinity of Rocky Comfort. They show an excess of lime over silica in the ratio of nearly 7 to 1. No. 2 is of the marl which immediately underlies the white chalk in the same vicinity. This marl is a combination of chalk, clay, and free silica in a very finely divided friable state. The ratio of lime to silica is nearly 1.5 to 1. An association of the chalk and marl, both of which are here accessible in large quantity, can be effected, it is believed, producing desired ratios of lime and silica for Portland cement.

Chalk of the Whitecliffs area.—Analyses Nos. 7, 8, and 9 are of the average white chalk occurring at Whitecliffs. The white chalk here and at Rocky Comfort belong to the same formation, and the analyses indicate that they are approximately of the same nature.

Marl similar to that below the chalk at Rocky Comfort occurs here also below the chalk, extensively exposed in the bluffs northwest of the village of Whitecliffs, 1 to 2 miles north of the Portland cement works at Whitecliffs Landing. A massive bed of siliceous, bluish or grayish white chalk, 25 feet thick, occurs immediately beneath the purer white chalk at the Portland cement works and in the bluffs facing the river immediately above the ferry. This siliceous chalk contains 3.8 parts of lime to 1 of silica—almost the proportions for a natural Portland cement rock. It contains 5 per cent of clay and a little more than 7 per cent of very fine siliceous sand. There is doubtless a small variation in the nature of this siliceous chalk vertically as in the purer white chalk above.

Chalk of the Saline Landing area.—Analyses Nos. 10, 11, 12, and 14 in the table show variations of the white chalk in the vicinity of Saline Landing. This is the eastward extension of the same chalk deposit that is found at Whitecliffs. Only the upper part of the chalk is exposed in this district, however, and the marl beneath is concealed by creek and river bottom silts. Marl similar in nature to that below, however, occurs here above the white chalk. The relations of the chalk and marl are described in the discussion of chalk of the Saline Landing area. Analysis of this marl from near the middle of the formation is shown in No. 13 of the table. Nos. 15 and 18 are of the same marl in the adjoining Washington area. In the case of No. 13 the relation of lime to silica is as 1 to 1.2, while in No. 15 it is as 1 to 2. Other analyses of the same marl formation are found in Nos. 23 and 24 from the Okolona and Deciper areas, respectively.

The clay of this marl is intimately distributed with the chalk and is to all physical appearances remarkably even in texture and quality. There appears no reason why an association of the marl and white chalk may not produce a correct mixture for Portland cement.

Saratoga chalk-marl.—This chalk-marl is described above in the three separate areas of Washington, Okolona, and Deciper as a siliceous dull-blue to whitish chalk rock. The free silica in this rock is in the form of very fine sand, perceptible to the touch but not ordinarily to the eye, except possibly as it occurs in the upper part of the formation. The lower 10 to 15 feet of the deposit is more chalky than succeeding beds. Analyses of this lower part of the chalk-marl are shown in Nos. 16, 21, 22, 25, and 26 of the following table. They are from the three areas of the Saratoga formation in this region and show very slight variation in composition. No. 16, which is of the chalk-marl from the railroad cut north of Washington, contains the highest percentage of chalk, the ratio of lime to silica being nearly 2 to 1. Nos. 21 and 22, from the Okolona, and 25 and 26, from the Deciper area, contain lime and silica in ratios of nearly 1.1 to 1. Dr. J. C. Branner reports analyses of two samples of the Saratoga chalk-marl from the lower shelly part occurring on the place of Mr. Thomas L. Jones, 2 miles west of Columbus, the material furnished by Mr. Jones. One analysis from the rock which was reported to have been plowed up indicates a quality equal to the high-grade chalk. The lime and silica in the other sample have the ratio of 3.3 to 1, almost the quality of natural Portland cement material. The writer visited the localities of these samples with Mr. Jones, found the normal siliceous chalk marl observed at numerous other places near the base of the formation, and was led to believe that the samples submitted were not of the average marl.

The Saratoga chalk-marl becomes more sandy toward the top until it is succeeded by a friable calcareous glauconitic sandstone. Analysis No. 19 is of the medial portion of the marl, giving an approximate ratio of lime to silica as 1 to 1.6.

From the records of these analyses it will be seen that in order to produce Portland cement from the Saratoga chalk marl it will be required to supply chalk instead of clay.

From the vicinity of Columbus to Saratoga, a distance of 5 miles, the crops of the white chalk and Saratoga chalk marl are separated by the outcrop of intervening marl 1 to 2 miles in width.

The chalk is not exposed and is not known to occur east of a point north of Columbus, so that it is separated from the Saratoga marl in the eastern part of the Washington, in the Okolona, and in the Deciper areas.

Considering the practically unlimited quantity of chalk associated with marls near Rocky Comfort, Whitecliffs, and Saline Landing, it is not believed, therefore, that the Saratoga chalk marl can be utilized as economically in the manufacture of Portland as the chalk of the Whitecliffs formation.

Notes on the Texas chalk.—By reference to table of analyses No. IV, page 737, it will be observed that the Texas chalk and marl approximate very closely in quality the Arkansas deposits, of which they are a southward extension. Nos. 1, 2, 3, and 4, Table IV, show the composition of the chalk proper, while No. 5 is of the chalk marl between the chalk and succeeding marl. The lime and silica in the marl, according to the analysis, have the approximate ratio required in a natural Portland cement rock. When calcined the product will contain approximately 60 per cent of lime and 24 per cent of silica. The succeeding blue marl and still higher greensand marl are in quality similar to those in the Arkansas section, occupying the same general positions in the stratigraphic section.

Explanation of analyses.—In the chemical analyses of the chalk and chalk-marl the alumina and iron oxide were not separated, for the reason that the percentage of the latter will average probably not exceeding 1 per cent.[a]

The reaction of the iron is believed to be practically the same as that of alumina in the manufacture of cement, and for this reason also they may be conveniently thrown together. In the case of the marl both below and above the white chalk, the percentage of iron oxide is greater, but it is believed that in no case will it exceed 2 per cent.

The alkalies—potash and soda—are omitted from consideration since it has been determined by a number of analyses of the chalks and marl that both together will average not more than about three-fourths of 1 per cent.

The amount of magnesia, it will be observed, is invariably less than 1 per cent.

The chemical analyses show that there are no substances that would impair the quality of Portland cement. As explained above, under "Processes of manufacture" (p. 730), the water and carbon dioxide are expelled from the rock, leaving the essential substances, silica, alumina, and lime, together with the nonessential small parts of magnesia and alkalies, as constituents of the cement. The quantity of the three essentials are found in the first three columns of the table, and from them, as a basis, the relative values of the chalk and marls as cement materials may be estimated.

By reference to the analyses of standard Portland cements, Table II, page 728, it will be seen that the proportions of lime to silica are nearly as 3 to 1.

[a] An average of 10 analyses of these chalks, made by the Arkansas Geological Survey gives 1 per cent of oxide of iron, the extremes being 0.42 and 1.91 per cent. Cement materials of Southwest Arkansas, by Dr. J. C. Branner: Trans. Am. Ins. Min. Eng., 1897.

TABLE III.—*Analyses*[a] *of chalk and chalk marl from southwestern Arkansas.*

No.	Silica, SiO_2, and insoluble.[b]	Ferric oxide and alumina, $Fe_2O_3+Al_2O_3$.	Lime, CaO.	Magnesia, MgO.	Carbonate of lime, $CaCO_3$.	Carbonate of magnesia, $MgCO_3$.
1	6.15	5.79	46.81	0.33	83.60	0.69
2	25.13	3.90	35.81	.61	64.32	1.28
3	8.53	1.22	48.50	.38	86.60	.78
4	7.32	1.26	49.94	.32	89.17	.67
5	27.28	5.00	34.81	.61	62.15	1.28
6	12.67	1.93	45.56	.43	81.35	.90
7	6.83	.95	50.41	.22	90.01	.46
8	7.86	1.30	49.55	.28	88.48	.58
9	7.97	1.09	49.64	.35	88.64	.73
10	14.68	2.15	45.03	.44	79.40	.92
11	4.91	.93	51.78	.30	92.46	.63
12	7.35	1.06	49.66	.34	88.67	.71
13	34.76	5.18	29.10	.71	51.95	1.49
14	12.65	1.66	45.85	.49	81.87	1.02
15	43.09	6.55	22.77	.92	40.65	1.93
16	21.90	2.35	40.57	.59	72.41	1.23
17	75.77	5.46	5.72	.91	10.21	1.91
18	30.68	4.91	32.60	.48	58.22	1.00
19	43.72	2.76	27.95	.42	49.90	.88
20	35.16	2.85	32.75	.43	58.48	.90
21	31.05	3.46	32.18	.69	57.41	1.44
22	31.01	2.93	34.63	.50	61.83	1.05
23	36.17	5.37	29.16	.48	52.06	1.00
24	32.26	7.05	17.24	.63	30.78	1.32
25	30.84	3.73	34.31	.60	61.26	1.26
26	30.29	3.31	34.77	.55	62.08	1.15
27[c]	5.45	3.87	....	....	88.58	....

[a] By chemists of the United States Geological Survey.

[b] "Insoluble" refers to insoluble in HCl. The other columns refer to the soluble portions only.

[c] Chalk at Medway, England, used in the manufacture of Portland cement. Quoted from Dr. J. C. Branner, on the Manufacture of Portland cements: Geological Survey of Arkansas, 188, Vol. II, p. 294.

References to analyses.

Rocky Comfort area.

1. SW. ¼ of the SW. ¼ of sec. 32, T. 12 S., R. 32 W., 2 miles southwest of Rocky Comfort. White chalk near the middle of the chalk formation.
2. NE. ¼ of the NE. ¼ of sec. 30, T. 12 S., R. 32 W., 2 miles west of Rocky Comfort. The chalky marl immediately below the white chalk.
3. Rocky Comfort, Little River County, Ark., near the NE. corner of the NE. ¼ of sec. 28, T. 12 S., R. 32 W., from lower middle part of the white chalk formation.
4. Same locality as 3, from the lower part of the white chalk formation.

Whitecliffs area.

5. NE. ¼ of the NE. ¼ sec. 35, T. 11 S., R. 29 W., top of the lower sandy marl bed beneath the white chalk.
6. Chalk bluff, Whitecliffs Landing, near the middle of the bluff in the lower part of the white chalk.
7. Chalk bluff, Whitecliffs Landing, 15 feet above the base of the purer white chalk.
8. Chalk bluff, Whitecliffs Landing. White chalk 10 feet below the top of the cliff.
9. Cement Works, Whitecliffs Landing. Average of the lower 35 feet of the purer white chalk in the quarry at the cement works.

Saline Landing area.

10. Saline Landing, Howard County, Ark. Sec. 35, T. 11 S., R. 28 W., from the middle of the chalk bluff.
11. NW. corner of the NE. ¼ of the SW. ¼ of sec. 30, T. 11 S., R. 27 W. White chalk from very near the top of the chalk formation.
12. Near the center of the SE. ¼ of the SW. ¼ of sec. 21, T. 11 S., R. 27 W., from near the middle of the white chalk.
13. Near the base of the knob 1 mile N. 15° E. from Saratoga, Ark. Chalky blue marl 100 feet above the top of the white chalk.
14. Near the center of the east side of the SW. ¼ of the NW. ¼ of sec. 22, T. 11 S., R. 27 W., from the lower part of the white chalk.

Washington area.

15. North cut on the railroad about 3 miles north of Washington, Ark. Chalky blue marl 40 feet below the base of the Saratoga chalk-marl.
16. Middle cut on the railroad about 2½ miles north of Washington, Ark., from the center of the cut in the lower part of the Saratoga chalk-marl.
17. South cut on the railroad about 2 miles north of Washington, Ark., from the greensand marl in the center of the cut.
18. SE. ¼ of sec. 25, T. 10 S., R. 25 W., head of Morisett ditch, from bluish chalky marl about 150 feet below the Saratoga chalk-marl.

Okalona area.

19. Forks of road 1½ miles south of Okolona, Ark., from middle of Saratoga chalk-marl.
20. SE. ¼ of sec. 4, T. 9 S., R. 22 W., about ½ mile southwest of Okolona, from sandy marl bed at base of the Whitecliffs chalk formation.
21. 2¼ miles south of Okolona on the Mat. Hardin place, from the lower 15 feet of the Saratoga chalk-marl.
22. Same locality as 21. Saratoga chalk-marl 16 feet above the base.
23. SE. ¼ of sec. 4, T. 9 S., R. 22 W., about 1½ miles south of Okolona, yellowish chalky marl about midway between the Whitecliffs and Saratoga formations.

Deciper area.

24. J. L. Bozeman's place, ⅓ mile northeast of the house, in the NW. ¼ of sec. 28, T. 7 S., R. 20 W., from the bluish chalky marl 4 feet below the base of the Saratoga chalk-marl.
25. Same locality as 24, from Saratoga chalk-marl 10 feet above the base.
26. Little Deciper Creek at Okolona-Arkadelphia road, from Saratoga chalk-marl about 10 feet above the base.

TABLE IV.—*Analyses of Texas chalk and marl.*

No.	Silica, SiO_2, and insoluble.	Ferric oxide and alumina, Fe_2O_3 and Al_2O_3.	Lime, CaO.	Magnesia, MgO.	Carbonate of lime, $CaCO_3$.	Carbonate of magnesia, $MgCO_3$.
1	5.77	2.14	50.45	0.28	90.15	0.58
2	5.94	1.72	48.73	....	86.57	....
3	10.32	6.56	45.30	....	79.75	....
4	11.31	7.50	42.61	....	76.47	....
5	15.98	8.47	38.86	....	70.60	....
6	48.02	20.95	14.26	....	24.62	....
7	60.82	21.30	3.66	....	6.51	....
8	23.55	1.50	39.32	.28	70.21	.58

1. Fresh rock from quarry, average material used in the manufacture of cement, Alamo Cement Works, 3 miles north of San Antonio, Tex.
2. Brushy Creek, Williams County, Tex., 100 feet above base of chalk.
3. Brushy Creek, Williams County, Tex., middle part of chalk.
4. Brushy Creek, Williams County, Tex., upper part of chalk.
5. San Gabriel River, Williams County, Tex., chalk-marl at top of white chalk.
6. Williams County, Tex., lower part of blue marl above the white chalk.
7. Williams County, Tex., greensand marl, central part above blue marl.
8. Average fresh rock from quarry, Texas Portland Cement Works, 3 miles west of Dallas, Tex., lower 20 feet of white chalk.

CLAYS AND SHALES.

Introductory statement.—The writer has not been able to make a study of the clays of southwestern Arkansas even in the immediate region of the occurrence of the chalk. All that is known of the clays in the State is contained in the manuscript report on clays by Dr. J. C. Branner. Unfortunately, the State has not yet published this report.

The information below on "Available clays" is from a publication on Cement Materials of Southwest Arkansas, by Dr. Branner.[a]

Available clays.—Clays, to be available for the manufacture of Portland cement, must, besides having the right composition, be sufficiently abundant, uniform in character, and convenient to transportation to make them cheap and trustworthy. In no case with which we are acquainted are the surface clays found in the immediate vicinity of the chalk deposits to be depended upon. Such clays are, as a rule, too sandy and too thin, and, above all, they are not of uniform composition. Reference is here made especially to the leached sandy clays, or "slashes," overlapping the chalk beds to the north and east of Rocky Comfort, and the clays of the bottom lands south and west of Whitecliffs, and those south, north, and west of the chalk exposures at Saline Landing. Fortunately, the Tertiary rocks which overlap the Cretaceous ones to the south and east contain an abundance of

[a] Trans. Am. Inst. Min. Eng., 1897.

excellent clays available for the manufacture of cement. Some of these clay beds are already being utilized for the manufacture of pottery at Benton and Malvern (Perla switch). At these two points the beds are on the railway. There are many other deposits on and near the railway that are as yet unused, and, indeed, generally unknown. Such occur about Arkadelphia, Malvern, between Malvern and Benton, between Benton and Bryant, at Olsens switch, and at Mabelvale. At Little Rock, also, there are extensive beds of both clays and clay shales, while scores of beds of clay shales may be found along the line of the Little Rock and Fort Smith road to Fort Smith and beyond.

The Tertiary clays at Benton, Bryant, Olsens switch, Mabelvale, and Little Rock are all horizontal or nearly horizontal beds dipping gently toward the southeast. They can be had in many places by stripping off a few feet of post-Tertiary gravel and soil; but in places the covering is too thick to be removed, and the clays can be had only by a system of drifts. In some instances the clay beds are so nearly uniform in character as to give rise to the idea that they have the same composition throughout. This, however, is true only in a limited sense; the clays do not seem to vary within the small areas thus far worked, but it is highly probable that they will be found to change to sands when a wide area is taken into consideration. This is not a serious objection to the deposits, however, as there is no possibility of the supply being exhausted.

Location of clays.—The following information regarding the local conditions of occurrence may be useful to those seeking information about the Arkansas clays. Only a few of the many known localities are here mentioned. On account of the geographical relations to the chalk beds, only those places convenient to railway transportation along the St. Louis, Iron Mountain and Southern Railway southwest of Little Rock are spoken of in this paper. Should a factory, on account of fuel or for other reasons, be located west of Little Rock, clays derived from the Carboniferous clay shales would have to be used. Of these there is no lack between Little Rock and Fort Smith.

Clays at Little Rock.—There are two general classes of clays at Little Rock available for cement manufacture: (1) The Tertiary clays that occur in horizontal beds in the southern and southwestern part of the city; and (2) the Carboniferous clay shales exposed in the railway cuts along the south bank of the Arkansas River, in the cuts west of the town, and in others west of Argenta.

There are other clays about Little Rock and Argenta, such as the chocolate-colored clays along the margins of the river bottoms, and the pinkish clays forming the high river terraces and used for making bricks on the north side of the river; but these latter two kinds of clays are not available for cement manufacture, partly because they are too sandy, but also because they are not homogeneous. An analysis of the pink clay of Argenta shows it to contain more than 83 per cent of silica.

The Tertiary clays were laid down, like the other Tertiary beds of Arkansas, as sediments in water. These strata were originally, and are still, very nearly horizontal. After the old sea bottom was elevated, however, the ordinary erosion cut down and washed away these soft sediments rapidly, so that now there remains on the hills but a small part of the original beds, and these have been still further obscured by gravels, clays, and soils that cover most of the region. The original bedding of these clays is to be seen only in a few gullies along the west-sloping hills in the western part of the city, and in the wells that penetrate them. They are of an olive-green to gray color, and upon exposure break up in small cuboidal fragments or, when thoroughly wet, pack together closely. They are cut in several gullies in the southwestern part of the city, and are penetrated by many of the wells.

The Carboniferous clay shales are well exposed in the railway cut near the upper bridge, and where the electric power house stands. Similar shales may be found here and there over a large part of Pulaski County, within the Carboniferous area. The objection to these shales is that they require grinding before they can be used in cement making, and the grinding, of course, makes them more expensive.

Composition of the clays.—The following analyses show the composition of the common run of the pottery clays and fullers' earths of Arkansas. These analyses are of representative samples, and a reasonable assurance may be given that the clays as found in place are as nearly homogeneous as clays ever are. Most of them contain some sand, usually quite fine. In those cases in which the percentage of sand is given the analyses are of the washed clay. This table might be greatly extended, as analyses of a large number of the clays of Arkansas are available. These, however, will give a correct idea of the general nature of the clays.

TABLE V.—*Analyses of typical Carboniferous clay shales from Arkansas, giving silica, alumina, ferric oxide, lime, magnesia, soda, potash, and water.*

No.	SiO_2.	Al_2O_3.	Fe_2O_3.	CaO.	MgO.	Na_2O.	K_2O.	Water.	Total.	Sand in air-dried clay.
1.....	53.30	23.29	9.52	0.36	1.49	2.76	1.36	5.16	100.48	......
2.....	62.36	25.52	2.16	.51	.29	.66	1.90	5.32	98.72	......
3.....	58.43	22.50	8.36	.32	1.14	1.03	2.18	6.87	......	......
4.....	65.12	19.05	7.66	.34	.31	.85	1.23	6.12	......	21.88
5.....	57.12	24.32	8.21	.72	1.74	.53	2.07	7.58	......	......
6.....	55.36	26.96	5.12	.30	1.16	1.03	2.69	7.90	100.52	......
7.....	51.30	24.69	10.57	.32	.63	.72	2.18	9.11	......	......
8.....	69.34	22.56	1.41	Trace.	Trace.	2.31	.04	5.12	......	......

1. Clay shale from railroad cut at south end of upper bridge, Little Rock.
2. Decayed shale from Iron Mountain railroad cut at crossing of Mount Ida road, Little Rock.
3. Clay shale from Nigger Hill, Fort Smith.
4. From Harding & Boucher's quarry, Fort Smith.
5. Clay shale from Round Mountain, White County, sec. 6, T. 5 N., R. 10 W.
6. From Clarksville, east of college.
7. From SE. $\frac{1}{4}$ of SW. $\frac{1}{4}$, sec. 31, T. 10 N., R. 23 W.
8. From NW. $\frac{1}{4}$, sec. 23, T. 1 N., R. 13 W.

TABLE VI.—*Analyses of typical Tertiary clays from Arkansas.*

No.	SiO_2.	Al_2O_3.	Fe_2O_3.	CaO.	MgO.	Na_2O.	K_2O.	Water.	Titanic acid.
1...........	63.07	23.92	1.94	0.23	Trace.	1.08	1.15	7.07	......
2...........	72.44	18.97	1.59	.18	Trace.	.91	1.35	5.39	......
3...........	69.95	22.34	1.44	Trace.	.08	1.18	1.28	5.98	......
4...........	71.09	19.86	1.81	.11	....	.81	1.45	5.67	......
5...........	65.27	18.75	7.34	.81	1.26	.81	1.10	6.88	......
6...........	64.38	17.29	8.25	1.11	.80	.42	1.41	6.95	......
7...........	63.19	18.76	7.05	.78	1.68	1.50	.21	7.57	......
8...........	64.49	23.86	2.11	.31	Trace.	1.82	.11	8.11	......
9...........	67.90	22.07	1.33	.05	.59	.38	1.15	6.86	......
10...........	48.34	34.58	1.65	.81	Trace.	1.26	.44	12.94	1.56
11...........	62.34	20.63	3.34	.17	.67	.33	.73	9.34	1.49
12...........	68.03	17.19	3.00	.81	1.00	.54	1.00	6.31	......
13...........	63.29	18.19	6.45	.31	2.44	Trace.	.56	......	......
14...........	76.33	16.04	1.24	By difference, .99				5.40	......
15...........	75.99	16.12	1.35	By difference, 1.45				......	......
16...........	73.24	19.61	1.04	By difference, .78				......	......
17...........	45.28	37.39	1.71	1.83	.29	......	......	13.49	......

1. Benton, Hick's bed, T. 2 S., R. 15 W., sec. 12,
2. Benton, Rodenbaugh, T. 2 S., R. 15 W., sec. 12.
3. Benton, Herrick & Davis's bank.

4. Benton, Henderson's pit, upper bed.
5. Mabelvale, A. W. Norris's well.
6. Olsen's switch, "fuller's clay."
7. "Fuller's earth," Alexander, T. 1 S., R. 13 W., SW. ¼ of SE. ¼ of sec. 8.
8. Benton, Woolsey's clay.
9. Ridgwood, T. 1 N., R. 12 W., SW. ¼ of NE. ¼ of sec. 25.
10. Benton, Howe's pottery.
11. Clay from T. 8 S., R. 15 W., sec. 4.
12. Clay from T. 8 S., R. 15 W., sec. 5.
13. Clay from T. 2 S., R. 13 W., S. ½ of sec. 13.
14. John Foley's, T. 13 S., R. 24 W., NE. ¼ of SE. ¼ of sec. 18.
15. Climax pottery, T. 15 S., R. 28 W., W. ½, SE. ¼ of sec. 5.
16. Atchison's, T. 4 S., R. 17 W., NE. ¼ of NE. ¼ of sec. 24.
17. Kaolin, T. 1 N., R. 12 W., sec. 36, Tarpley's.

According to Professor Jameson[a] clays for Portland cement should not contain less than about 60 per cent of silica in combination.

PORTLAND CEMENT INDUSTRY IN ARKANSAS.

WHITECLIFFS PORTLAND CEMENT WORKS.

A Portland cement plant was erected at Whitecliffs Landing, on Little River, 1 mile south of Whitecliffs post-office (see Pl. LIII), and a branch railroad constructed from the river opposite the plant to Wilton on the Kansas City Southern Railroad in 1895. On account of litigation between those financially interested the works have been idle since May, 1900. The members of the company and those involved in the litigation were scattered, and it was not practicable to obtain a correct history of operations. Operations were resumed late in 1901, with the name of the company changed to the Southwestern Portland Cement Company.

Plant, processes, and material.—The works were constructed of the most approved machinery, including crushers, ball mills, and a steam-drying plant. Four continuous dome kilns were utilized, and the bricks passed upon cars from the forming machine through the drying plants to the elevators, which conducted them to the kilns. From the kilns the clinker returned on cars to the crushing plant and mills.

The quarry, which is shown in the rear of the works, is elevated so that the chalk descends by gravity to the reducing machines. Clay silt from the river bottom land near by was utilized as a mixture with the chalk. The economy of using this material, because of its convenient location, instead of clays of high grade was a mistake, it is believed.

Coal and coke of high grade in large quantity occur in eastern Indian Territory on or near the Kansas City Southern Railroad. This fuel may be transported by rail at small cost directly to the cement works.

Market and transportation.—Until the year 1900 the nearest cement plant of any nature to the Whitecliffs works was at San Antonio, Tex., a distance of 375 miles. In this year a Portland cement plant has been erected at Dallas, Tex., where a mixture of Upper Cretaceous chalk from the southern extension of the Whitecliffs formation and

[a] Portland Cement, by Charles D. Jameson. Iowa City, 1895, p. 17.

underlying clay marl is utilized. The product from this plant will naturally supply a large part of the North Texas market at least. The Whitecliffs cement should supply all Arkansas, Indian Territory, central Oklahoma, a large part of Louisiana, and possibly western Tennessee and Mississippi. Transportation north and south is direct by the Kansas City Southern, northeast and southwest by the St. Louis, Iron Mountain and Southern, and east and west by the Choctaw, Oklahoma and Gulf and the Memphis and Choctaw railroads.

The chalk deposits at Rocky Comfort are within 1 mile of the Arkansas and Choctaw Railroad, which connects with the Kansas City Southern at Ashdown. This road is extending westward to tap the Missouri, Kansas and Texas at Ardmore, Ind. T.

The chalk of the Saline Landing area is more than 10 miles by direct line from the St. Louis, Iron Mountain and Southern and the Arkansas and Louisiana railroads. Saline Landing, however, which is upon the chalk, may be accessible to the St. Louis, Iron Mountain and Southern Railway at Fulton by West Saline River, which is navigable to small steamers during a large part of the year.

INDEX.

D.

G.

M.

Y.

O