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COAL RESOURCES OF SOUTHEASTERN MASSACHUSETTS ASSESSED IN 1942

by

Newton E. Chute, 1907-

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By L. W. Currier

The Rhode Island formation underlies the greater part of the Narragansett basin in Massachusetts, and is known to contain several coal beds. Some of these beds have been mined (at several places) in the vicinity of Mansfield, Massachusetts. Considerable money has been invested in attempts to develop a coal mining industry in this area, but operations have never been successful for several reasons, as set forth in the body of this report.

It has seemed desirable to review the history and geology of the coal area at this time in order to determine if possible the potential value of this field as a coal producer. The following facts have been determined.

Geologic data upon which to judge the coal resources of the State are scant indeed. Bedrock exposures, upon which such judgment must depend largely, are few and not well distributed, so that both the lithology of the Rhode Island formation and its structure are not adequately determinable. In general it can be fairly stated that, so far as available data indicate, the geologic conditions for the occurrence of coal beds are favorable over most of the basin, but that the number of coal beds, their continuity, and their thicknesses are entirely indeterminable except through a thorough and very expensive program of core drilling.

The few structural data at hand suggest that the Rhode Island formation has been strongly deformed into a series of steeply limbed

folds, so that the lower part of the formation, in which all the known coal beds occur, lies deeply below the surface over most of the area. Thus most of the coal beds would require that deep shafts be sunk for their development. Moreover, most of the actual mining would be done on steeply inclined beds, making a simple and relatively less expensive room-and-pillar method of development impossible.

One of the most serious drawbacks is the lack of knowledge concerning continuity and thickness of the coal beds. In this respect the historical data are discouraging, for the coal beds encountered in the few mines of the area were found to be too thin, and for the most part too greatly variable in thickness to permit successful exploitation, even at the shallow depths to which these mined developments were limited. It is obvious that the greater the depth to which mining is carried, the greater the expense of mining, and the thicker and more continuous the coal beds must be to insure financial success.

Although in that part of the basin that lies in Rhode Island most of the coal beds have been found to be graphitic, it appears that the coal in Massachusetts is definitely less metamorphosed so far as it could be observed. The Massachusetts coal is clearly of anthracite grade, and according to historical reports was usable with reasonable success. Also its calorific power was found to be moderately high. Very few analyses of the coal are available, but those at hand indicate an exceptionally high ash content, although the ratio of fixed carbon to volatile hydrocarbon is favorable. Nevertheless the high ash

content and lower than average calorific power, if general for the field, marks the Massachusetts coal as definitely inferior to Pennsylvania anthracite.

The coal mined at Mansfield was found to be characterized by considerable shearing effects and some granulation. These features, if persistent throughout the field, would be detrimental in causing marked variation in thickness and continuity of the beds, and in promoting a greater proportion of fine sizes.

It should be pointed out that all the mines and prospects of the Mansfield area are situated near the present border of the coal basin. This may also be the approximate limit of the original basin; where conditions of deposition may have been somewhat different from those that prevailed in the more central parts of the basin. Thus it is quite possible, though entirely unsupported by any known facts, that the coal beds elsewhere may be thicker and more continuous. On the other hand, they would occur at increasingly greater depths toward the center of the field or axes of the folds.

Clearly, the nature of the coal beds, and the tonnages of minable coal, could only be determined by drilling. There are such meager data available for choosing sites and areas for drilling that such a project would partake considerably of the nature of "wild catting". Closely spaced, deep holes over a large area would be necessary to explore thoroughly the coal possibilities, and the project would be very expensive. On the basis of known facts, admittedly meager, such a project cannot be urged.

COAL RESOURCES OF SOUTHEASTERN MASSACHUSETTS

by

Newton E. Chute

Purpose of Report

This report presents the results of a geologic study of the coal deposits of southeastern Massachusetts, particuiarly of the area around Mansfield. The study, supervised by L. W. Currier, was made under the cooperative geologic project of the Massachusetts Department of Public Works and the U.S. Department of the Interior, Geological Survey, at the request of the Massachusetts Planning Board.

Acknowledgments

Many people have assisted this survey. The writer is especially indebted for information concerning the former coal mining operations to: Mr. F. A. Bentley and Mr. C. C. Scheffy, owners of the Hardon mine; Mr. George Bolling, Director of the Brockton City Laboratory of the Water and Health Department; Miss Jennie Copeland, Mansfield historian; Mr. Walter Packard, formerly president of the Bristol County Coal Company; Mr. J. K. Milliken, treasurer of the Mount Hope Finishing Company; Mr. F. D. Greany, owner of the Tremont St. mine; Mr. H. Morse, Mansfield town clerk; and Mr. Howard Paine, Mansfield electrical engineer.

Introduction

Large easily mined coal deposits of usable quality would be of great value to Massachusetts, particularly in war time. Every effort has been made in this study to evaluate the probable occurrence, quantity, and quality of the coal deposits in southeastern Massachusetts but unfortunately it is impossible from surface observations alone to ascertain adequately the coal resources of this area. Only by means of widespread and systematic underground exploration, accomplished best by core drilling, can the coal resources be determined. All the available data concerning the coal resources is analyzed in this report in order to indicate the feasibility of such an exploration program and where it is most likely to be successful.

Occurrence of the Coal

The coal in southeastern Massachusetts occurs interbedded with sandstone, conglomerate, and shale or slaty shale beds of the Rhode Island formation of Carboniferous age. These rocks, together with other Carboniferous sedimentary rocks that are not coal bearing, underlie about 900 square miles of southeastern Massachusetts and Rhode Island and comprise what is known geologically as the Narragansett Basin (see Plate 1).

The Carboniferous sedimentary rocks of this region have been divided into four formations which are summarized in the table below with the oldest at the bottom and the youngest at the top.

TABLE OF CARBONIFEROUS FORMATIONS IN NARRAGANSETT BASIN

Formation name and maximum thickness	Description
Dighton conglomerate 2000'	Coarse quartzite and granitic pebble congiomerates, with finer conglomerates and sandstone.
Rhode Island formation 10,000'	Grey feidspar—rich sandstones and grey to black shales or slates with considerable interbedded pebble and granule conglomerate and some coal beds.
Wamsutta formation 1000'	Red massive sandstone that is in part quartzitic with more or less red shale or slaty shale. Underlies only the northern part of the Narragansett Basin.
Pondville conglomerate 100'	Chiefly grey granule conglomerate rich in feldspar (arkose) with some pebble conglomerate. Underlain by pre-Carboniferous igneous and metamorphic rocks, chiefly the Dedham granodiorite.

Due to the fact that the Pondville conglomerate and the Wamsutta formation are the oldest of the Carboniferous formations, they appear at the surface only around the margin of the basin and in an upfolded area in the vicinity of North Attleboro (see plate I). The Rhode Island formation extends over most of the Narragansett Basin and is the only one of these Carboniferous formations known to contain any significant amount of coal. It is estimated by Woodworth (8, p. 150)* to have a maximum thickness of 10,000 feet as compared with a total thickness of only 2,000 to 3,000 feet for all of the others.

*See bibliography at end of report

For the most part bedding is poorly developed in the Rhode Island formation. Individual beds cannot be traced very far because of the scarcity of outcrops and the general similarity of the beds. Plant fossils are found in places but they are of little value in correlating beds. The lack of distinctive beds adds to the difficulty of interpreting the structure and tracing coal beds.

Locally in downfolds or synclines the Rhode Island formation is overlain by erosion remnants of the Dighton conglomerate. Woodworth (8, p. 104) estimated that this formation has a maximum thickness of 2000 feet. The Dighton conglomerate occurs in three elongated areas in the Massachusetts portion of the Narragansett Basin (see Plate 1). One extends southwestward from Dighton, another extends southwestward from a point near Taunton, and the third and smallest area is near and southwest of Attleboro. The Dighton conglomerate does not contain coal, and where present it conceals the potentially coal-bearing Rhode Island formation.

Coal has been found widely distributed in the Rhode Island formation. It has been mined at Portsmouth and Cranston in Rhode Island and near Mansfield in Massachusetts, also it has been reported found in Wrentham, Foxboro, Raynham, Bridgewater, West Bridgewater, and Middleboro, Massachusetts.

The coal is so easily weathered and eroded that, with few exceptions, it is not naturally exposed at the surface. Nearly all of the coal discoveries have been made in excavations such as wells and ditches. So little is known concerning the Rhode Island formation that no

significant part of it can be definitely said to be non-coal bearing. Woodworth (9, p.9) was of the opinion, however, that the majority of the productive coal beds are in the lower 3000 feet of the formation.

Although the coal beds cannot be located by surface observation, the structure of the Rhode Island formation can be determined in a general way. Originally the beds were nearly horizontal. Great forces applied in a northwest-southeast direction deformed them, chiefly by folding, so that now the beds are inclined and form large folds several miles across. In most places the folds trend northeast-southwest. The trends of the folds change somewhat, however, from nearly east-west in the northern part of the area to nearly north-south in the southern part in Rhode Island (see fig. 2).

In the Mansfield area the beds are in the form of a downfold or syncline that has a general but irregular trend nearly east-west (see plate II). The coal beds at West Mansfield are on the south side of this downfold as is indicated by the fact that the beds in the mines dip toward the northwest.

History of Coal Mining at Mansfield

Coal mining began in Massachusetts in 1835 following a discovery of coal in a well in West Mansfield by Alfred Hardon, and was carried on for brief periods until about 1920. Today the three principal mines are filled with water and very little can be seen at the surface. The only available information concerning the coal in Massachusetts is afforded by the records of these mining operations, hence a careful analysis of the history of the mining is of considerable importance

in evaluating the coal resources.

The Massachusetts Mining Company, the Mansfield Mining Company, and the Mansfield Coal Company were organized in 1835. According to Hitchcock (4, p. 104) the Massachusetts Mining Company began to sink a shaft in 1835 on the farm of Alfred Hardon (see plate II). The shaft penetrated two beds of coal at a depth of about 25 feet; the upper bed was reported to be 5 feet thick and the lower one 1 foot thick, the two being separated from each other by 10 inches of barren rock. The shaft was sunk to a depth of 64 feet where drifts were driven in opposite directions along the bed. Hitchcock (4, p. 104) reported that the drifts were run for 150 feet each way from the shaft and that about 1500 tons of coal were taken from the mine up to the time he visited it in October 1838. He also stated (4, p. 104) that General Samuel Chandler, who was manager of the mine at the time, reported 4 coal beds on the property of the company. Two of these beds were opened up sufficiently to determine their thickness to be over 5 feet.

The Mansfield Coal Company sank a shaft 64 feet deep near the center of Mansfield, but according to Hitchcock (4, p. 109) they found only a little coal. This is probably the shaft on Chestnut street off South Main Street (see plate II).

The Mansfield Mining Company (4, p. 109) sank a shaft a short distance west of Tremont Street, about three-quarters of a mile northwest of the Hardon Mine. The shaft was sunk to a depth of 84 feet, but only one coal bed a few inches thick was found. Hitchcock (4, p. 109) stated that "a drift was then commenced at the bottom of this

shaft, horizontally towards the southeast so as to cross the strata. This had not been pushed far when a bed of coal was struck about 10 feet thick, though on exploring it laterally for a few feet, it was found to be somewhat irregular; as indeed most of the beds are in the region (4, p. 109). Several other small excavations for coal were made in the Mansfield area about this time but they were unsuccessful in finding commercial deposits. Hitchcock (4, p. 114) mentioned two shafts a few rods apart in Foxboro where good coal was obtained, but they were already filled up and abandoned when he visited the area in 1838. The pits were said to be situated two miles north of the Mansfield coal beds (6, p. 331) but the writer has not been able to locate them or to determine how much coal was found. All of these coal mines and prospects in the Mansfield area were closed by the end of 1838.

The next coal mining venture in Mansfield, according to Hitchcock (6, p. 331) was undertaken about 1848 by the Mansfield coal and mining Company. A vertical shaft 10 feet in diameter was sunk 170 feet deep about 1000 feet northwest of the Hardon Mine. From the shaft a drift was run 660 feet southward and other drifts totalling about the same length were driven. In all it is reported that 13 beds of coal were crossed, none of which were thick. Squeezing of the coal beds during folding caused them to become irregular and to vary in thickness from 6 or 8 feet to a few inches within a short distance. Miss Copeland (1, p. 86) stated that mining stopped here about 1854 or 1855, and estimated that 5000 tons of coal were taken from the mine during its operation.

Coal mining was at a standstill in Mansfield from 1854 until 1883, at which time a new company was formed and diamond drilling started. According to Miss Copeland (1, pp. 87-88) this company also unwatered and cleared out the Sawyer mine, which had ceased operations in 1854, but found it had been practically worked out. Although no mining was done by this company, the diamond drilling was continued over a period of about 8 years. Most of the drilling was done in the vicinity of the Hardon mine where one hole was put down 1100 feet and another 800 feet. Mr. Howard Paine informed the writer that the drilling was done by M. E. Harrington and Son. Both of the Harringtons have since died and the writer has not been able to find any one who knows the results of the drilling or any records with the exception of the coal analyses published by A. B. Emmons (3, p. 515). (See p. 18 of this report).

After the company ceased operations nothing more was done until 1909 or 1910 when the Massachusetts Coal and Power Company was organized. This company started on a large scale. Considerable stock was sold and the company bought a large tract of land near West Mansfield. One or more of the old mines was worked enough to produce some coal but no new mines were opened. Many people in Mansfield are of the opinion that this company was organized as a stock selling scheme and had no intention of doing any serious mining.

The next mining operations were by the Bristol County Coal Company from about 1917 to 1920. The company was started by Miss Vose of Boston but was soon taken over by Mr. Walter Packard of Avon. All of the work was done on the old Hardon mine, which was pumped out and

partly explored. Because of the large volume of water that had to be handled and the inadequate pumping equipment, most of the money available was spent in unwatering the mine. According to Mr. Packard (personal communication) only about 20 to 25 tons of coal were mined before operations ceased. The last mining venture in the Mansfield area began about 1920 when the Mount Hope Finishing Company of North Dighton, in search of coal for its plant, unwatered and prospected the old shaft near Tremont Street. Mr. J. K. Milliken, treasurer of the company, informed the writer that the mine was pumped out at considerable expense but insufficient coal of good quality was found to justify further operations.

In order to clarify the history of the individual mines a table is included here to summarize in chronological order the principal mining enterprises.

TABLE OF COAL MINING OPERATIONS IN MANSFIELD

Company	Hardon Mine	Sawyer Mine	Tremont St. Mine	Others
Mass. Mining Co. organized 1835	Sank shaft in 1835, 5-foot coal bed found at 25 ft. At 64 ft. 150-foot drifts run. 1500 tons coal mined in 3 years			
Mansfield Mining Company organized 1835			In 1835 sank shaft 84 ft., coal bed few inches thick in shaft. At bottom of shaft ran a drift SE. short distance to 10-foot coal bed that was discontinuous and soon mined out	
Mansfield Coal Company organized 1835				Several shafts, one of which was 64 ft. deep, were sunk in Mansfield. One is on Chestnut St.
Six farmers organized company in 1849				Held 867 acres on both sides of S. Main St. Only 3 or 4 holes dug before company dissolved

Company	Hardon Mine	Sawyer Mine	Tremont St. Mine	Others
Mansfield Coal & Mining Company organized 1848 Managed by B. F. Sawyer		In 1848 shaft sunk 170 ft. deep and 10 ft. wide, tunnel run 660 ft. at bottom of shaft. Other tunnels totalled 700 ft more. 13 beds of coal found but were mostly thin and irregular. Spent $98,000 to $100,000 and mined 2500 to 5000 tons of coal much of which was used in own boiler. Operations stopped about 1854.		
Company formed in 1883	Drilled in vicinity of Hardon mine; in one place to 1100 ft. and in another to 800 ft. Drilling continued intermittently over a period of 8 years.	Shaft cleared out but no mining done		
Mass. Coal and Power Company. Organized 1909 or 1910	Bought up large tract of land but did only enough mining to get out a few tons of coal			
Bristol County Coal Company. Organized 1917 or 1918	Pumped out Hardon mine, took out 200 to 25 tons of coal before operations ceased about 1920			
Mount Hope Finishing Co.			Pumped out and prospected Tremont St. shaft about 1920 but found little coal and soon stopped work	

Quantity of Coal

The occurrence and character of the coal found in the West Mansfield mines is probably fairly representative of the coal that might be found elsewhere in the coal-bearing rocks of this part of Massachusetts. With this in mind the quantity and quality of the coal found in the West Mansfield mines is summarized below in so far as it can be ascertained from the available records.

One important feature observed in the mines is that the coal beds commonly do not maintain uniform thickness for any considerable distance. Hitchcock (6, p. 331) reported that 13 beds of coal were found in the Sawyer mine but stated that "they are very irregular, sometimes swelling out to six or eight feet in thickness and then pinching up to a few inches". As stated above, the same irregularity was noted by Hitchcock (4, p. 109) in the Tremont St. mine.

Coal beds may be more or less lenticular as a result of the conditions of deposition. The variation in thickness referred to here, however, is the result of squeezing when the rocks were folded. The squeezing thickened the coal beds in places and thinned them in others. This variation in thickness considerably increases the difficulty of estimating the coal reserves of known beds. Diamond drill records would be especially difficult to interpret because of the uncertainty as to whether a thickened or a thinned portion of a coal bed had been penetrated.

The Mansfield coal mines provide no indication concerning the quantity of coal that may be expected to exist elsewhere; however,

they do demonstrate that coal-forming conditions recurred several times while the rocks of the Rhode Island formation were being deposited. This is substantiated by the reported discoveries of coal at other localities.

Some people to whom the writer has talked have the notion that the Hardon mine, the Sawyer mine, and the Tremont Street mine are all on the same coal bed. All available evidence, however, indicates that these mines are on different coal beds. Hitchcock (6, p. 331) stated that although the beds in the Sawyer mine are not very far from the beds in the Hardon mine they have little correspondence. The beds in these mines trend or strike northeast and are inclined or dip toward the northwest. According to Hitchcock (6, p. 331) the dip of the beds in the Sawyer mine is from 30 to 70 degrees northwest and the dip in the Hardon mine 53 degrees northwest. These mines lie along a northwest-southeast line across the trend of the beds and, therefore, they should be in different beds unless the rocks have been faulted, for which there is no available evidence (see plate II).

As many as 22 different coal beds, most of them too thin to be of any commercial value, have been reported found in the three mines. The abundance of coal beds in the small area explored leads to the belief that there are other undiscovered coal beds in the Rhode Island formation in Massachusetts. It is impossible to predict, however, whether they would be of sufficient thickness, continuity, and quality to be of any commercial value.

Inasmuch as the coal beds of the West Mansfield coal mines are on the south limb of a syncline, they should also be found on the north limb if they have sufficient continuity (see fig. 3). However, only two discoveries of coal on the north limb of the syncline near Mansfield are known to the writer. One was made between 1835 and 1838 in two closely spaced pits located somewhere in Foxboro and the other was made in a well in the northern part of Mansfield. Mr. James Bellow told the writer that in 1888 he dug a well 26 feet deep in the back yard of the Patrick Shields residence, located on the east side of Oakland Street, two houses north of Shields Street. Coal was struck in the bottom of the well but water came in so fast that the well was not dug deeper and the thickness and quality of the coal bed were not determined.

Although practically nothing is known or can be determined from surface observation concerning the quantity of coal that remains unmined in Massachusetts, some inferences can be drawn from the history of the mines concerning the advisability of reopening them. The most productive of all the mines appears to have been the Sawyer mine which is estimated by Miss Copeland (1, p. 86) to have produced about 5000 tons of coal in all; much of the coal, however, was burned in the company's own boiler. Mr. B. F. Sawyer, a lawyer from New York, is said (1, p. 85) to have managed the mine efficiently from 1848 to the time it was closed down in 1854. It is reasonable to suppose, therefore, that the mine was closed because there was insufficient coal to mine profitably. About $100,000 (1, p. 86) was spent before the capital was exhausted and the mine closed.

The company that began operations in 1883 pumped out the Sawyer mine (1, p. 86) with the intention of working it but found that the mine had been worked out. From this it would seem that before the Sawyer mine could be worked profitably new coal beds would have to be found. The mine is full of water and the openings are so extensive that it would be very expensive to pump them out for further exploration. In view of these difficulties it is very doubtful if this mine could be worked again successfully.

The Hardon mine produced about 1500 to 2000 tons of coal, most of which was mined between 1835 and 1838 by the original company. Hitchcock (5, p. 130) was of the opinion that this mine was well managed during these early operations for he wrote, "The explorations at this spot have been carried forward under the direction of General Samuel Chandler, of Lexington, who seemed to me to have managed the whole concern with remarkably good judgment, and to have brought the principles of science to bear upon practice with singular success". The Bristol County Coal Company, which began operations in 1917 or 1918 on the Hardon mine, spent considerable money in unwatering the mine. Walter Packard informed the writer that there is a bed of coal at the bottom of the shaft at a depth of 200 feet or so and that, as nearly as he can remember, it is from 3 to 3 1/2 feet in thickness. His company did not do any development work in the drifts from which the majority of the coal had been taken by previous companies. This mine also has doubtful value. Presumably it was abandoned because it was worked out by the original company. Any plan to reopen this mine should take into

consideration high pumping costs, as a large amount of water must be handled, as well as the necessity for considerable exploration to find workable coal beds in advance of development.

The Tremont Street mine is actually only a prospect inasmuch as it was not developed and did not have any commercial production. It was unwatered and examined at considerable expense about 1920 by the Mount Hope Finishing Company. Mr. J. K. Milliken, treasurer of the company, informed the writer that the small amount of coal found was too low grade for mining; therefore, before this mine could have any future value new coal beds must be found.

Quality of the Coal

Considerably more coal has been mined in Rhode Island than in Massachusetts. The graphitic character of much of the Rhode Island coal has gained wider publicity for it than its importance merits. As a consequence, the Massachusetts coal, which, like the Rhode Island coal, also occurs in the Rhode Island formation, is commonly but incorrectly considered to be similarly graphitic. The Massachusetts coal has not been as severely metamorphosed as some of the Rhode Island coal and is not known to be graphitic. Analyses show that the coal should be classified as anthracite but some of it is nearly of semi-anthracite rank.

All of the Massachusetts coal seen by the writer is considerably fractured and sheared. The fractures make the coal somewhat more permeable to water and may cause it to break up more readily than unfractured coal.

A serious defect of the coal appears to be its high content of ash. The following analyses of coal from the Hardon mine were made by Mr. George E. Bolling, chemist and director of the laboratory of the Brockton Health and Water Departments. The coal samples analyzed were collected by Mr. Walter Packard's brothers, now deceased, and there is no record as to where the samples were collected. The analyses were made at different times between August and December 1919.

Analyses of Coal from the Hardon Mine, W. Mansfield[1/]

Sample	Moisture	Volatile matter	Fixed carbon	Ash	Sulphur (determined separately)	B.t.u.
1	2.92	3.74	66.78	26.56	1.02	10,633
2	3.98	3.70	55.57	36.75	.52	8,591
3	4.40	2.75	66.93	25.92	.45	10,296
4	2.48	2.93	71.24	23.35	.44	10,940

1/ analyst, George E. Bolling

According to Emmons (3, p. 515), the following two analyses were made from cores of diamond drill holes that cut the same coal bed at different depths. The holes were put down in the vicinity of the Hardon mine. In one of the holes the coal bed was cut at a depth of about 90 feet and in the other at a depth of about 850 feet.

Analyses of Coal Cut from the same Bed in Drill Cores from near the Hardon Mine

Sample	Moisture	Volatile matter	Fixed carbon	Ash	Sulfur	Fuel ratio
1	1.02	3.76	74.24	20.97	.56	19.74
2	3.08	6.22	79.68	11.02		12.81

Some analyses of Pennsylvania anthracite are included here for comparison with the anthracite from Mansfield.

Analyses of Pennsylvania Anthracite*

Water	Volatile matter	Fixed carbon	Ash	Field
2.2	6.6	84.2	7.0	Southern Fishtail
3.5	3.7	83.2	9.6	Southern
5.3	3.2	83.1	8.4	Eastern Middle
3.5	3.7	81.0	11.8	Southern
5.0	5.2	80.5	9.3	Northern
3.7	3.9	79.9	12.5	Western Middle
5.2	4.4	79.0	11.4	Southern
2.3	7.8	78.8	11.1	Western Middle
2.5	8.3	76.3	12.9	Shamokin dist.
2.6	8.3	76.2	12.9	Lykens dist.

*H. G. Turner, Anthracites and semianthracites of Pennsylvania: Am. Inst. Mining and Metallurgical Engineers Trans., vol. 108, pp. 330-343, 1934.

Moore (7, p. 105) gives the range of sulfur content of commercial anthracite as from 0.17 to 2.60 per cent and the range in calorific value from 9,230 to 13,298 B.t.u.

Many people have reported that the West Mansfield coal burns readily and gives satisfactory heat in ordinary stoves and heaters. In fact, there are so many favorable reports concerning the coal that the writer has little doubt but that locally the coal could be used satisfactorily for both domestic and commercial heating. Mr. C. C. Scheffy of West Mansfield informed the writer that he used coal from the Hardon mine in a hot-water heater all of one summer and found it very satisfactory. Mr. Howard Paine of Mansfield had a similar experience. He told the writer that he used coal from the same mine one winter for heating his house and found it entirely satisfactory. Mr. F. H. Tarment of Foxboro tried out some of the coal from the Hardon mine in a doughnut stove and according to him (personal communication) it gave good results.

Hitchcock's reports cite testimonials concerning the quality of the West Mansfield coal. In his State report of 1841 he quoted Mr. William B. Dorr, who was clerk of the Massachusetts Mining Company, which worked the Hardon mine from 1835 to 1838, as follows (5, p. 131): "'The quality of the coal' says Mr. Dorr, 'has afforded entire satisfaction to those who have taken the pains to give it a thorough trial, and to investigate its distinctive properties. Several of the directors use it exclusively for fuel, in open grates, cylinder stoves, and cooking ranges. It is found to ignite and burn best with a very moderate

draught; and broken to about the size of a butternut. Uniformity in size is of course desirable. Under favorable circumstances, little difference is found in comparison with the best Pennsylvania anthracite, whether in relation to facility of ignition or intensity and durability of heat'".

In the same report Hitchcock also mentioned other tests. He wrote: "In my report of 1838 I adduced the testimony of Captain Bunker and 35 passengers of the steamboat President, on board of which the Mansfield coal was used during a trip from Providence to New York. They regarded this coal 'fully equal to the Pennsylvania coal in all essential properties'. In a Report on the Coal mines of the state made to the legislature of Massachusetts in 1839, we have a similar certificate from 16 of the inhabitants of Mansfield who had used the coal in their stores and homes. They state that 'the coal taken from 26 to 50 feet in depth was poor, and much of it scarcely capable of combustion; but 'that taken from the depth of 60 feet and upwards, is equal to the Pennsylvania coal in all respects excepting a larger portion of waste'".

Summary

1. Usable anthracite coal is known to occur in the Rhode Island formation in Massachusetts but it is impossible to determine how much coal is available except by extensive underground exploration. New coal beds cannot be located in this region by surface observation alone.
2. Woodworth has expressed the opinion that most of the workable coal beds are in the lower 3000 feet of the formation. However, no

significant part of the Rhode Island formation, which covers approximately 500 square miles in Bristol, Plymouth, and Norfolk Counties and is estimated to have a maximum thickness of 10,000 feet, can be definitely said to be non-coal bearing.

3. The coal mined at West Mansfield is anthracite. It is not metamorphosed as much as some of the Rhode Island coal, and is not known to be graphitic.
4. Coal has been mined in Massachusetts only at West Mansfield, but the coal there is probably representative of the mode of occurrence and quality of the coal that may be found elsewhere in the Narragansett basin of Massachusetts.
5. The West Mansfield coal beds show considerable variation in thickness and the coal is much fractured due to squeezing and shearing of the beds during folding.
6. The Massachusetts coal tends to have a very high ash content that ranges from about 10 to 35 per cent according to all available analyses, otherwise the coal is of good quality. Numerous favorable reports from users indicate that the coal makes a satisfactory fuel for many purposes.

Conclusion and Recommendations

The data available concerning the coal-bearing Rhode Island formation is so meager that it is impossible, except in a very general way, to outline its coal producing potentialities. A prospecting program undertaken in this region would be essentially a wildcat enterprise based largely on chance. Thin non-commercial coal beds may be numerous

and widespread but there is no assurance that thick extensive coal beds capable of producing large quantities of coal could be found.

So far all of the coal mining efforts in Massachusetts have ended in failure. The writer has no exact figures but the records suggest that nearly half a million dollars were spent in prospecting and development work on coal in Mansfield. In all as much as 5000 to 7000 tons of coal may have been mined, but the mines never got much beyond the development stage and brought very little in returns to their owners.

The failure of the mines cannot be blamed entirely on mismanagement or on lack of funds. General Samuel Chandler who managed the Hardon mine from 1835 to 1838 and B. F. Sawyer who managed the Sawyer mine from 1848 to 1854 both are said to have been very able men who invested their own money in the mines and made every effort to make the mines successful. Others who came later were equally intent on making the mines pay if possible. The history of the mines clearly shows that insufficient coal was found to make them profitable.

Should determination of the coal resources of the Narragansett Basin be considered important enough to justify a prospecting program, even though the results may be negative, the following suggestions concerning procedure are offered.

The methods of underground exploration applicable to this region include:

1) diamond drilling

2) sinking shafts and driving drifts and cross cuts from them

3) trenching

4) prospecting old mines

Diamond drilling is generally the fastest and most economical of these methods. Trenching and shaft sinking could be used locally to supplement diamond drilling where the glacial deposits are thin and other conditions are favorable.

The question of where to drill is not easily answered. It is obvious that the drilling should be limited to the Rhode Island formation, for the Pondville conglomerate, the Wamsutta formation, and the Dighton conglomerate are not known to contain any significant amount of coal. A logical procedure would seem to be to start a drilling campaign in the vicinity of the West Mansfield mines, where coal is known to occur. From there the drilling could be extended as far as the money available would allow.

The location, number, and depth of the holes to be drilled should be planned to give maximum results for the money expended. It would probably be necessary to decide first whether a relatively small area should be tested thoroughly with closely spaced holes or whether it is preferable to prospect a larger area in less detail with the holes more widely spaced. A seemingly feasible plan would be to prospect the area in the vicinity of the Mansfield mines carefully with closely spaced holes (see fig. 3) but to prospect elsewhere with holes spaced a mile or more apart except where a discovery is made. Some diamond drilling was done in the vicinity of the Hardon mine about 1883. A. B. Emmons (3, p. 515) reported analyses of a coal bed found in one of these

holes at a depth of 90 feet and in another at a depth of 850 feet. Unfortunately the exact locations and the logs of these holes are not known.

The drill holes might be placed at random or arranged in a definite system. The writer believes that the best results would be obtained by locating the holes according to a grid pattern with rows of holes both across and parallel with the strike of the beds. For example, at the Mansfield mines the beds strike northeast, so that the rows of drill holes would be aligned northwest across the strike and northeast parallel to the strike. The holes in the rows across the strike should be more closely spaced than those parallel to the strike because of the folded condition of the beds, which permits different strata to be tested across the strike (see fig. 3).

In order to explore the maximum thickness of strata with each hole it would be necessary to drill the holes perpendicular to the plane of the beds. The attitudes and spacing of 500-foot holes to test all of the beds is illustrated in fig. 3. If the holes were 1000 feet deep they could be spaced twice as far apart and still test all of the beds.

The details of the structure of the Rhode Island formation are not well enough known to permit the drilling pattern to be fully determined before a drilling campaign is started. A geologist should examine the cores as the drilling progresses and modify the pattern as the added information may require. Thus the fault shown on plate II along the west side of Mansfield needs to be taken into consideration in planning a prospecting program around Mansfield, but more information is needed

concerning the exact location of the fault and the magnitude of the displacement.

The fourth method suggested for exploration, namely, to unwater one or more of the old mines for prospecting is to be considered a second choice. The Tremont Street mine never has shown any promise and would be a very poor risk. The Sawyer mine is apparently practically worked out, also the underground workings are so extensive it would be a big expense to unwater the mine. The Hardon mine seems to offer the best chances of success, perhaps only because there is so little definite information concerning what remains in the mine. Mr. Walter Packard's brothers, who worked the mine for him from 1918 to 1920, and their engineer have since died. Mr. Packard himself is not sufficiently familiar with the underground workings to be able to say exactly how much coal was still in sight when the mine was abandoned. Mr. Packard informed the writer that as he remembered it there is a coal bed about 3 to 3 1/2 feet thick at the bottom of the shaft, at a depth of about 200 feet. Mr. Packard's coal analyses already cited are probably of this bed. Mr. P. A. Bentley of West Mansfield, who owns the property on which the mine shaft is situated, described the mine somewhat differently. He said that the shaft is 300 feet deep on a 65 degree incline and that it cuts two coal beds, one at a depth of about 60 feet and the other at about 180 feet. He does not know the thickness of the beds. Hitchcock stated that a bed 5 feet thick was cut by the shaft at a depth of 25 feet but that drifts were located and the mining was done at a depth of 64 feet. There is no certainty as to how much

coal could be obtained from this mine. Judging by the experience of Mr. Packard's company it would cost considerable to pump it out and keep it dry.

The amount of money that can justifiably be spent on an exploration program is difficult to decide. Obviously the more money available the more complete and determinative the results would be. If it were not feasible to appropriate as much as $100,000, the work might be started on $25,000 to $50,000 to be supplemented later by additional allotments if the initial results proved sufficiently favorable. In any case the sum to be spent on exploration for coal should be large enough to permit drilling at least 10 or 12 holes 500 to 1000 feet deep. No estimate of the cost of the diamond drilling is included here as that necessarily must be determined by qualified experts in that field.

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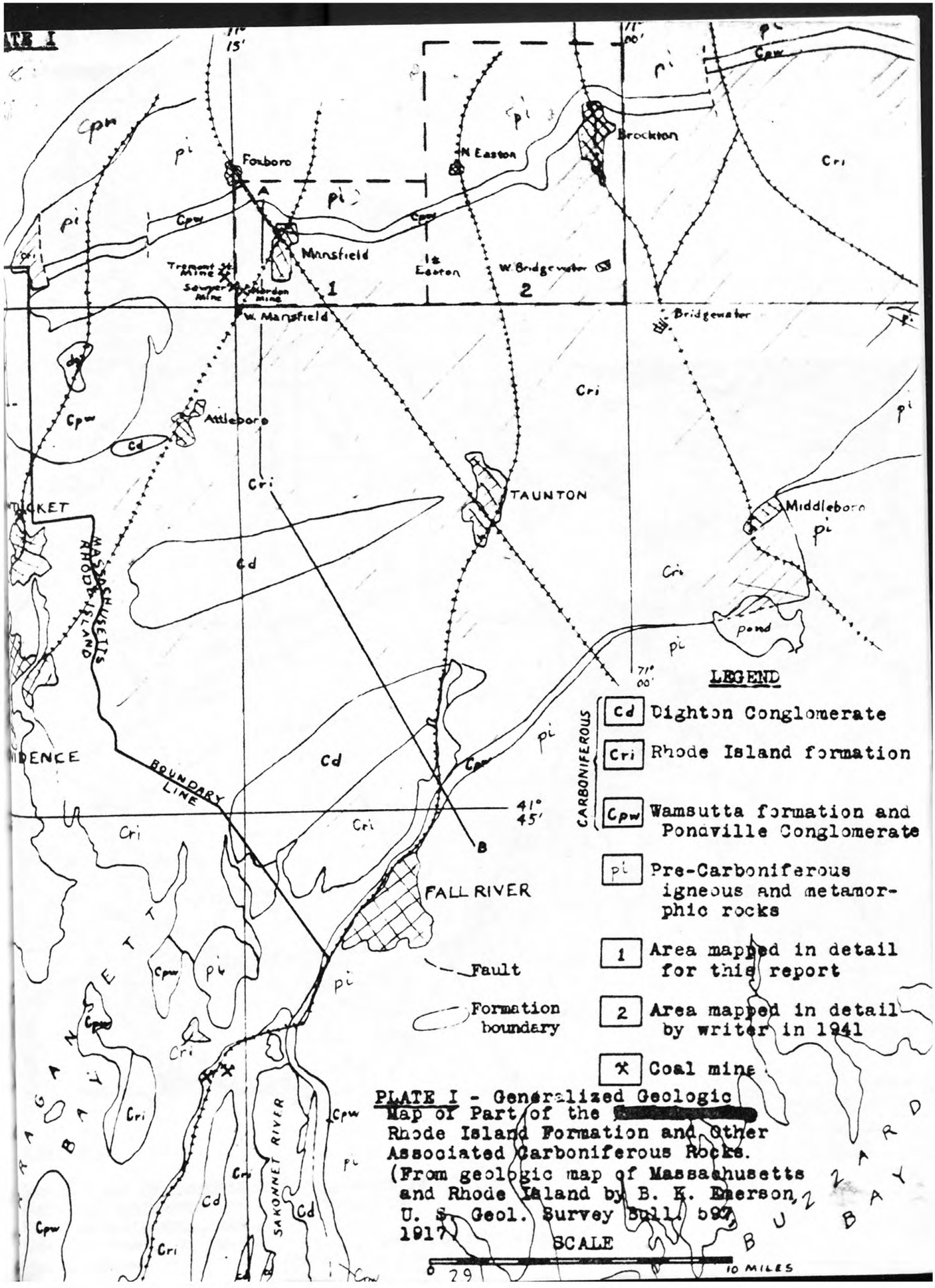


PLATE I - Generalized Geologic Map of Part of the [redacted] Rhode Island Formation and Other Associated Carboniferous Rocks. (From geologic map of Massachusetts and Rhode Island by B. K. Emerson, U. S. Geol. Survey Bull. 597, 1917)

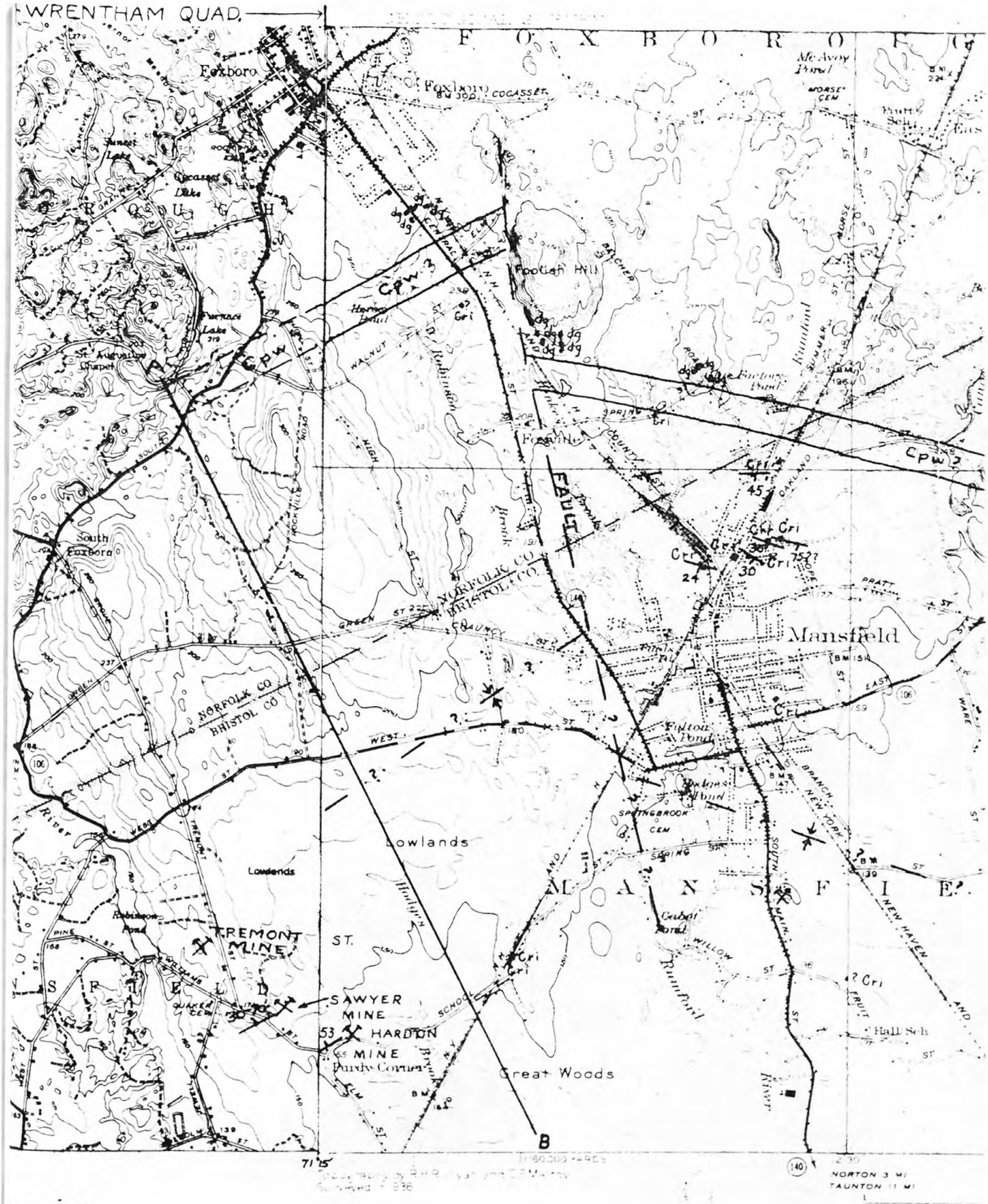


PLATE II.

GEOLOGIC MAP OF CARBONIFEROUS COAL BASIN IN MANSFIELD QUADRANGLE AND ADJACENT PART OF WRENTHAM QUADRANGLE, MASSACHUSETTS.
(Adapted from B. K. Emerson, U.S.G.S. Bulletin 597, with slight modifications by Newton E. Chute, July 1942.)

MASSACHUSETTS
MANSFIELD QUADRANGLE

Cri - Rhode Island formation
Cpw - Pondville conglomerate and Wamsutta formation
dg - Dedham granodiorite, pre-Carboniferous

Outcrop

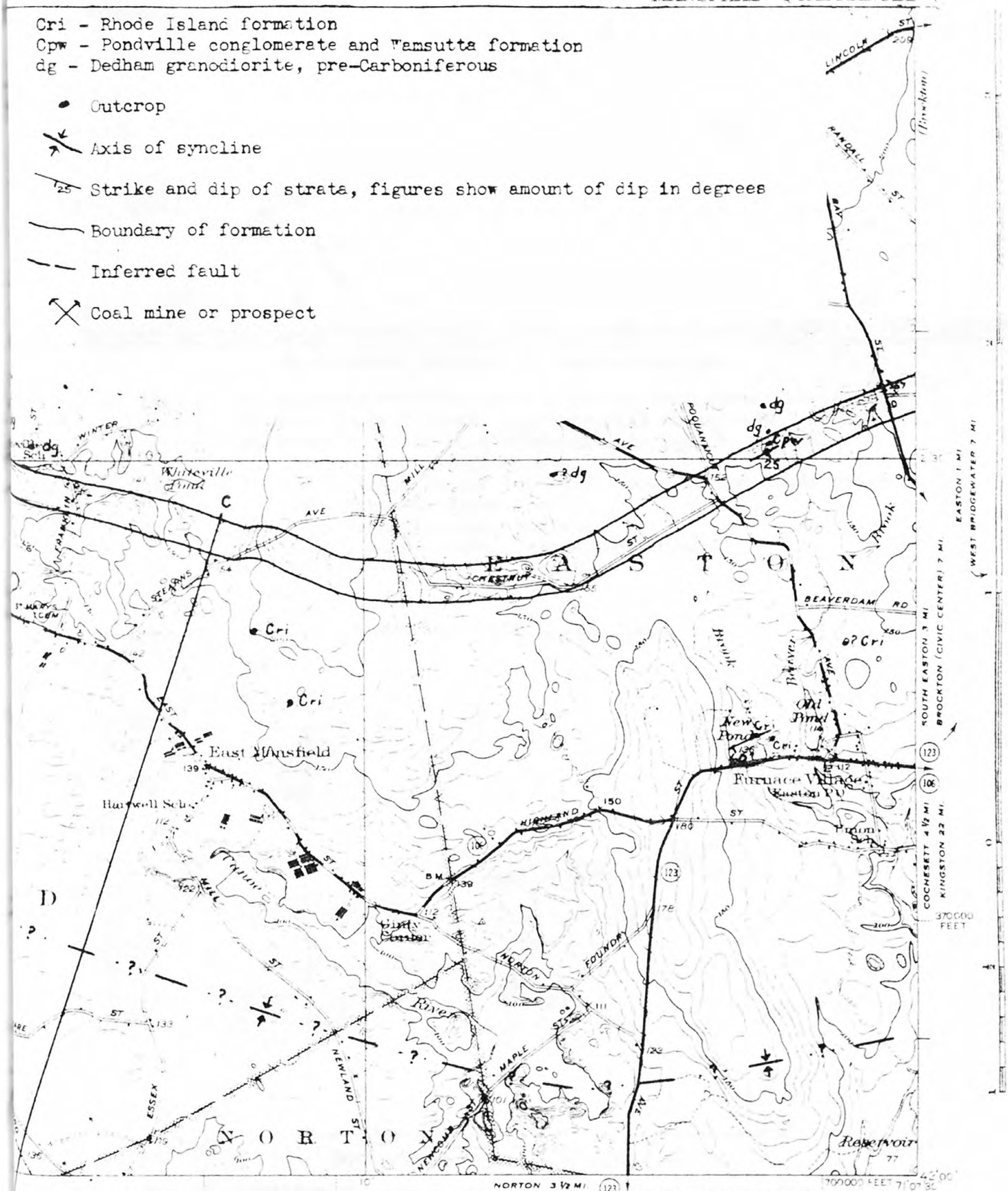
Axis of syncline

Strike and dip of strata, figures show amount of dip in degrees

Boundary of formation

Inferred fault

Coal mine or prospect



Scale 1:9680

0 1 Mile
0 5000 Feet
0 1 Kilometer

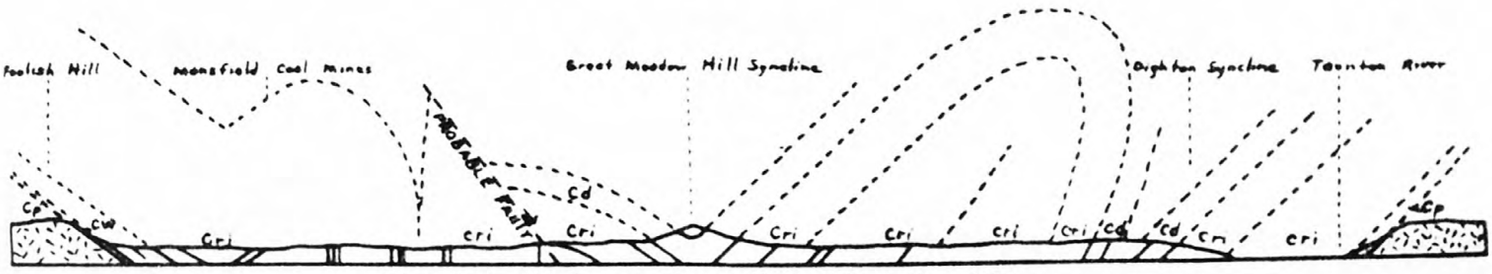
Contour interval 10 feet
Datum is mean sea level

Polyconic projection. 1927 North American Datum
10000 yard grid based on U.S. zone system A
10000 foot grid based on Massachusetts
rectangular coordinate system

ROUTES USUALLY TRAVELED
HARD IMPERVIOUS SURFACES
OTHER SURFACE IMPROVEMENTS
1940
U.S. ROUTE
STATE ROUTE

MANSFIELD MASS.
Edition of 19
N4200-WT1075/7.5

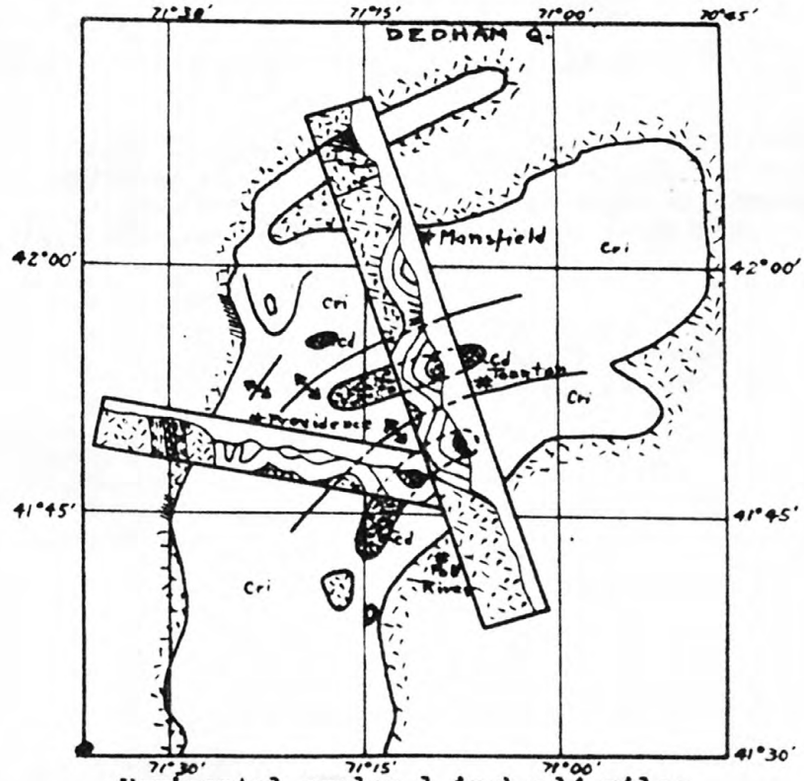
30b



Horizontal scale: I inch = 2 miles

Fig. 1. North-south vertical section across Narragansett basin from Foxboro to Fall River, approximately along line A-B, Plate I. Slightly modified from Woodworth (8) fig. 8, p. 122.

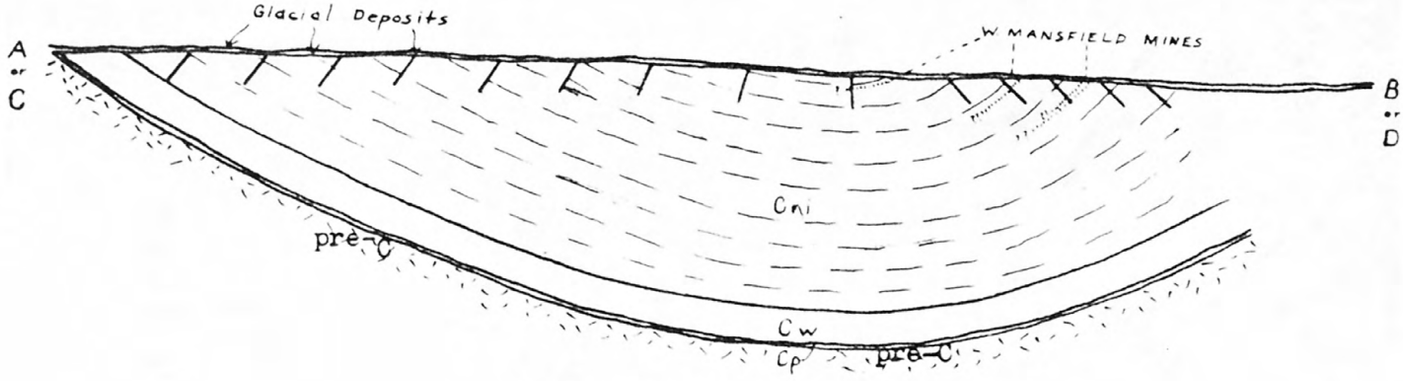
Cd - Dighton conglomerate
Cri - Rhode Island formation in which coal beds occur.
Cw - Wamsutta formation
Cp - Pondville conglomerate
Igneous rocks, pre-Carboniferous.



Horizontal scale: 1 inch = 14 miles

Fig. 2. Outline map and general cross-sections of the Carboniferous basin to show major structural relationships. Modified slightly from Woodworth (8) fig. 9, p. 125.

Cd - Dighton conglomerate
Cri - Rhode Island formation, Wamsutta formation and Pondville conglomerate
Igneous rocks, pre-Carboniferous.



Scale: 2 inches = 1 mile

Fig. 3. Generalized cross-section to illustrate the structure of the Carboniferous strata along lines A-B and C-D, Plate II. Lines show how 500-foot diamond drill holes might be arranged to explore systematically the Rhode Island formation.

Cri - Rhode Island formation
Cw - Wamsutta formation
Cp - Pondville congomerate
pre-C - pre-Carboniferous, chiefly igneous, rocks
~~~~ Known coal beds and possible extensions
~~~~