MAGNITUDE AND QUALITY OF MICHIGAN'S COAL RESERVES

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Introduction

This work, "Magnitude and Quality of Michigan's Coal Reserves", was done for the U. S. Bureau of Mines under Grant Agreement G0155165, J. Kalliokoski, Principal Investigator.

Michigan produced some 46 million short tons of coal between 1860 and 1949, and maintained an annual production rate in excess of one million t.p.y. between 1900 and 1923 (Fig. 1; Cohee, 1950). The increasing demand for energy products and the proximity of the Michigan coal basin to potential markets has revived interest in this region. This study is a compilation centered around the quality and quantity of Michigan coal with special emphasis given to those considerations which bear on the future development potential of this resource. Towards this end the major efforts have been the production of updated coal deposit maps and a reevaluation of the coal reserves. The report itself provides an introduction to these maps and estimates, and serves as a brief summary of geologic thought concerning the Michigan coal basin.

Previous Work

The previous studies of the Pennsylvanian rocks in Michigan have centered largely around coal. This early work has been summarized by Shideler (1965) as follows:

"The earliest investigations of the Pennsylvanian system date back to approximately 1835 and were originally initiated by the discovery of coal - bearing strata in the vicinity of Jackson, Michigan. The first systematic appraisal of the areal extent of the Pennsylvanian coal measures was conducted between 1838 and 1841 by the state geologist, Douglass Houghton, and his associates, Bela Hubbard and C. C. Douglass.

The results of these initial investigations were subsequently modified and augmented by more detailed studies conducted by Alexander Winchell, Carl Rominger, and C. D. Lawton between 1861 and 1882. It was during this period that Winchell subdivided the coal measures of Michigan into three strati - graphic units, which subsequently became the basis of the present system of Michigan nomenclature. Rominger and Lawton contributed substantial information in their descriptions of numerous stratigraphic sections throughout the state.

At the turn of the century, industrial economic factors necessitated the exploration and development of native coal resources, thus establishing the coal mining industry in Michigan. With the advent of mining operations, impetus was provided for a more extensive investigation of the Pennsylvanian system.

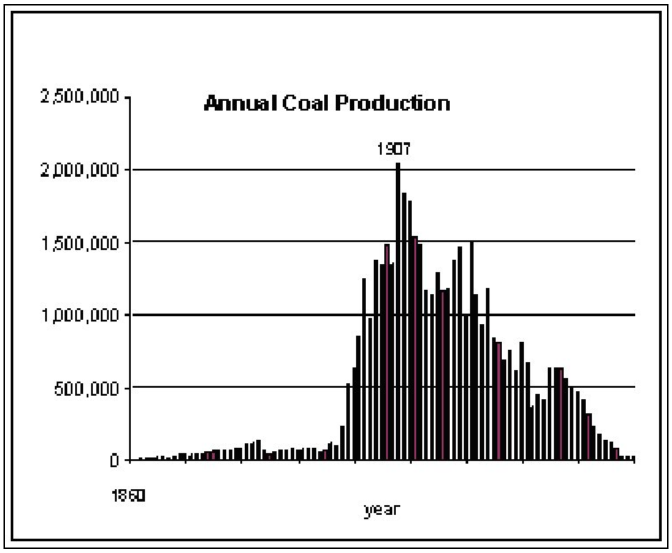

Figure 1 - Coal Production in Michigan, 1860 to 1949. (G.V. Cohee, 1958)

In response to the growing interest in native coal resources, state geologist, Alfred C. Lane, prepared a comprehensive report on the coal of Michigan (1902). In his report, Lane compiled and synthesized the results of the work of several men over a period of approximately 15 years. The report placed primary emphasis on the origin, occurrence, and development of coal, but also contained significant information regarding the stratigraphy and lithology of the Michigan coal measures. Also included in the report were identifications of Michigan flora and fauna made by David White and G. H. Girty of the U. S. Geological Survey. On the basis of plant identifications, the Michigan coal measures were tentatively correlated as Pottsville.

After Lane's report of 1902, the next 25 years witnessed the appearance of additional publications, which included those of W. N. Gregory (1902, 1912), W. F. Cooper (1906, 1909), and R. A. Smith (1912), as well as subsequent reports by Lane.

In 1928, Dr. W. A. Kelly of Michigan State University began an extensive study of the Pennsylvanian system, which culminated in 1936 with his publication on the "Pennsylvanian System in Michigan". During the course of his investigations, Dr. Kelly contributed valuable information regarding Michigan faunas and floras, lithologic and stratigraphic descriptions, as well as a detailed review of work previously done on Pennsylvanian strata in Michigan (1930, 1931, 1933).

Other contributions to the present state of knowledge were made by

R. B. Newcombe, whose work resulted in a modification of the areal distribution of Pennsylvanian strata in Michigan. From the standpoint of paleo - botanical investigations, Dr. C. A. Arnold of the University of Michigan conducted detailed studies of the Pennsylvanian flora of Michigan, which helped to establish a basis for correlating Michigan strata with neighboring Pennsylvanian coal basins (1934, 1949, 1950)."

The findings of these early workers, and of Cohee, whose work is described below, serves as a basis for the excellent summary on Pennsylvanian strata in Chapter V of "The Geology of Michigan" by Dorr and Eschman (1970), quoted at length on later pages.

A report on the quality of Michigan coals was prepared in 1948 by Andrews and Huddle (1948). In addition to listing all of the available data, they also provide brief descriptions of the mines from which some samples were collected. This is the only source for such information, and in that the report was prepared near the close of the coal mining period, it contains virtually all of the analytical data available on Michigan coal.

A few years later, in 1950, C. V. Cohee and others prepared a report on the production and reserves of Michigan's coal, obtaining most of their data from coal borings and mine maps, and from site visits. This report has become the standard reference on the subject, and is used in such publications as "Coal Resources of the United States, January 1, 1974" (Averitt, 1975), and in the U.S.B.M. Circular 8680 (Thomson and York, 1975). In 1951 Cohee studied the Pennsylvanian system further with regard to its lithology and thickness variability of the sediments (Cohee, 1951).

The most recent paper (Wanless and Shideler, 1975) is based on the thesis by G. L. Shideler (1965), cited earlier. He studied the Pennsylvanian sequence to establish the characteristics of the strata and the distribution of the various lithologic types, in order to establish paleogeologic patterns. He based his study on 425 carefully selected drill holes for which the loqs and samples were on file at the University of Michigan (Figure 2). The results of his study are presented in a series of cross sections, isopach and paleogeologic maps, some of which accompany this report.

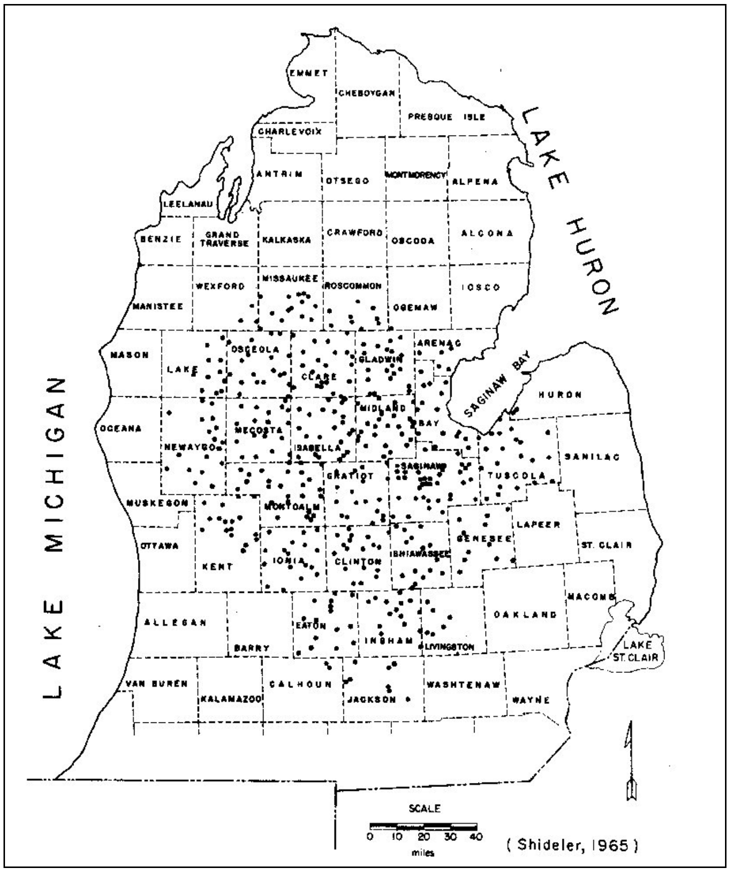

Figure 2 - Locations of drill holes used for mapping of Pennsylvanian sedimentational patterns.

Geology of the Michigan Coal Deposits

Introduction

All of Michigan's past coal production has come from rocks of Pennsylvanian age in the southeast portion of the coal basin (Map bA). Mining conditions were challenging in that the coal beds are extremely variable in distribution and thickness, often pinching out in a matter of feet. These paragraphs will try to explain the geological setting that produced these conditions.

General Setting of the Basin

The coal basin, located centrally in Michigan's Lower Peninsula (Fig. 3), lies within a larger structural basin, the Michigan basin, bounded on the northeast and north by the Canadian Shield, on the northwest by the Wisconsin arch, on the southwest by the Kankakee arch, on the southeast by the Findlay arch, and on the east by the Ontario arch. Some of these tectonic features are quite old, and have tended to restrict deposition within the basin, or to isolate the Michigan depositional area from adjacent areas. For example, during Silurian time, the isolation facilitated the accumulation of enormous thicknesses of evaporites.

The present basin area became a subsidence feature in Silurian time, as evidenced by a thicker sequence of sedimentary rocks near the center of the basin than on the margins H This is shown also by thicknesses of Pennsylvanian strata (Figure 3). Throughout the history of the basin, most of the sedimentary rocks record rather shallow marine conditions during sedimentation with only rather rare and sporadic periods of tectonically induced uplift, resulting in non - deposition, the erosion of previously deposited beds, or the deposition of fluviatile or subaereal sedimentary rocks. One of the resulting erosional features is the unconformity between the slightly folded marine Bayport limestone of Mississippian age and the deltaic and fluviatile coal - bearing rocks of Pennsylvanian age (Figure 4).

In early Pennsylvanian time the area was a shallow basin and a series of rivers flowed into it from the east. Thus the sedimentary conditions ranged from marshy fluviatile - deltaic on the east to shallow brackish marine on the northwest and west (Figures 5, 6, 7). In time all of the Pennsylvanian rocks became covered by red beds of late Jurassic age.

During the Glacial Period the area was overridden by glaciers at least twice, eroding an unknown quantity of material from the bedrock in the basin. During their retreat the glaciers left the coal basin covered by a thick mantle of glacial sands, gravels and clays, in places six hundred feet deep (Map 10B).

Nature of the Early Pennsylvanian Strata

Dorr and Eschman (1970) have published a succinct interpretative description of the sedimentary rocks deposited in the time period; the description applies well to the paleogeographic maps of Shideler (Figures 5, 6, 7):

"... The land had risen at the close of the Mississippian, so the Pennsylvanian Period actually began with Michigan in the emergent condition inherited from that prior period. Thus, when deposition of sediments finally began again, later in the Early Pennsylvanian, the basal deposits were laid down upon an erosion surface cut across the folded and slightly inclined layers of preceding periods. A slight angular unconformity resulted. Later in the Early Pennsylvanian .. the first of many minor marine advances carried the sea across the state from the north and west and some marine Pennsylvanian strata accumulated. Deltas then grew from east to west into the Michigan Basin (Cohee, 1965, p. 219). A relict of the sea persisted along the west edge of the state in spite of this delta growth, and it received red shales while elsewhere the basal sands of the Saginaw Formation were accumulating. The margins of this shallow sea then began to fluctuate, new seaways extended into the state from the south and southwest, and the central and western parts of the Michigan Basin were alternately marine areas, then

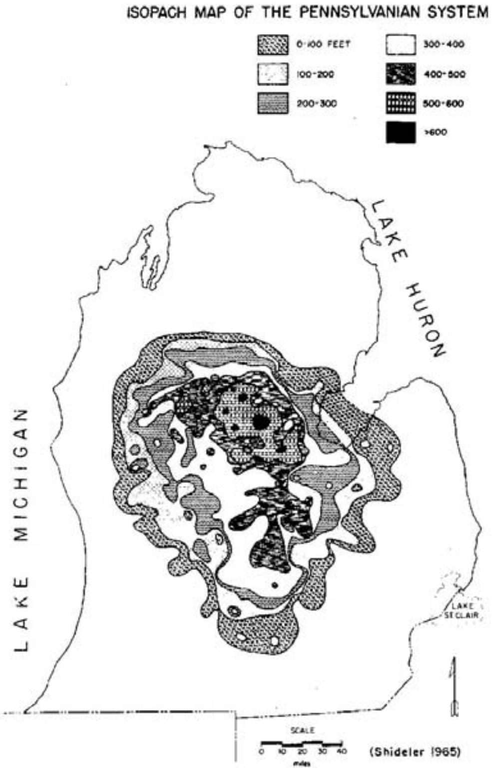

Figure 3 – Isopach Map of the Pennsylvanian System

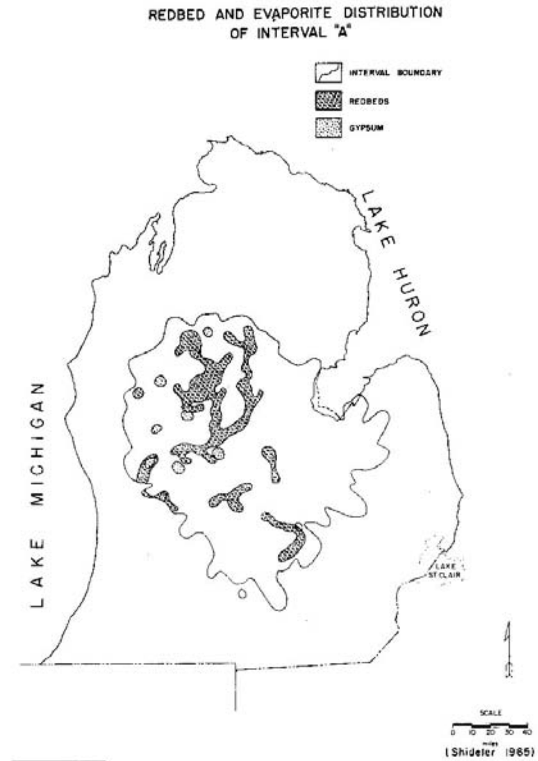

Figure 5 – Redbed and Evaporite Distribution of interval "A"

Figure 4 – Pre- Pennsylvanian Paleogeography map

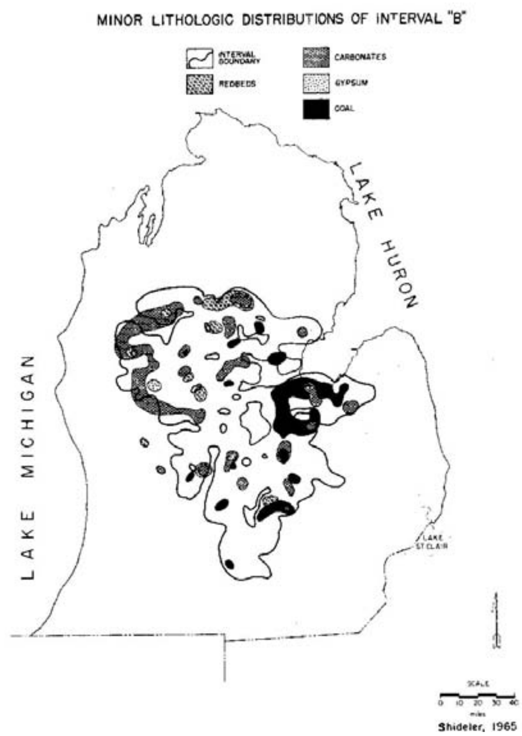

Figure 6 – Minor Lithologic Distributions of Interval "B"

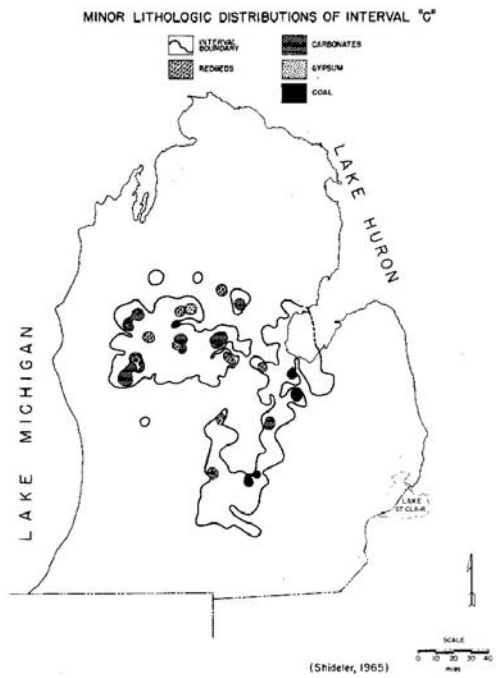

Figure 7 - Minor Lithologic Distributions of Interval "C"

swamp - lands, then emergent coastal plains tranversed by streams. A series of sedimentary deposits, including the marine Verne Limestone, accumulated under those varying conditions to form the Saginaw Formation. That formation now consists of alternating and intertonguing stream and river channel sands, river floodplain silts and clays, shallow water marine or tidal swamp shales and limestones, and swamp - laid coals. The occasional marine limestones and shales contain the fossil remains of salt or brackish - water animals, thus providing that those deposits originated in a marine or brackish - water environment .... Some of the shales contain both marine fossils and broken plant remains, suggesting deposition either on marine tidal flats or deltas. Kelly (1936) recognized several "cycles" of deposition represented by alternating continental and marine or brackish - water sediments. Several minor unconform - ities in the sedimentary record represent brief times of emergence of the land. The Pennsylvanian deposits of the Saginaw Formation with the included uncon - formities thus represent a series of marine transgressions and regressions often referred to as "overlap" and "offlap" deposits Typical examples of cyclic deposition in the Saginaw Formation can be seen today in some of the shale quarries in the vicinity of Grand Ledge near Lansing The sandstones of the Saginaw Formation often are discontinuous lenses of highly variable thickness. They include abundant fossilized leaves, tree trunks, and roots of land plants and represent stream channel deposits. The medium to light gray shales and siltstones, also rich in land plant fossils, and with poorly developed and irregular stratification, are river floodplain and swamp deposits. The upper parts of some of the shales often are bleached to a light gray, the stratification destroyed, and ironstone concretions common. These zones are called "underclays" and are thought to be old soil zones perhaps formed under cover of swamp waters. Burrowing soil dwellers, such as worms, and root growth are thought to have been the causes of destruction of the stratification. Darker gray to black siltstones and shales with thin, regularly bedded layers that split easily and evenly, and containing both land plant fragments and marine or brackish - water invertebrate animals, such as the mud - loving brachiopod Lingula, were deposited on muddy marine tidal flats. Coal seams are common. These often are lensing or discontinuous, no one layer continuing for any great distance before thinning out and ending Some of the swampy depressions were oxbow lakes and sloughs left behind when ancient rivers abandoned one meander bend for another. Other depressions were tidal swamps formed in overlying areas near sea level.

The Verne Limestone near the middle of the Saginaw Group is widespread in the western and central parts of the basin and represents a period of extensive marine invasion; fossil marine invertebrates are common in it (Dorr and Eschman, 1970, p. 128, 130)."

Distribution of Coal

At the beginning of our work we recognized that all of the coal production had been from the eastern and southern parts of the basin, but we also noted that the glacial cover was not nearly as thick here as it was in the northwestern part of the basin. For these reasons, and despite the writing of Dorr and Eschman (1970) and the work of Shideler (1965), we reviewed all of the available drill logs in order to determine whether the western and northwestern areas had in fact less coal. The results of our findings in Map 10A show that there are very few coal (or carbonaceous shale?) occurrences outside of the six county area, and that the distribution of past production is a good indicator of the geographic distribution of coal beds. It should be pointed out that our map contains all of those coal occurrences shown by Shideler in his paper (1965), and shown schematically in his sections reproduced here as Figures 8 and 9.

The geological basis for this restricted distribution of coal is explained in the quotation from Dorr and Eschman (1970) reproduced above. From a more graphical basis, Figures 8 and 9 show marine shales to be more abundant in the western part of the basin, and Figures 5, 6, and 7 show a similar distribution for gypsum and carbonate, both indicative of marine conditions, and for redbeds indicative of marine conditions or certainly of conditions not conducive to the growth and accumulation of plant matter such as now preserved as coal. The evidence points quite clearly to more marine conditions having prevailed in the western portion of the basin, and thus to conditions not conducive to the growth and accumulation of coal - producing plants. We conclude from our study that all

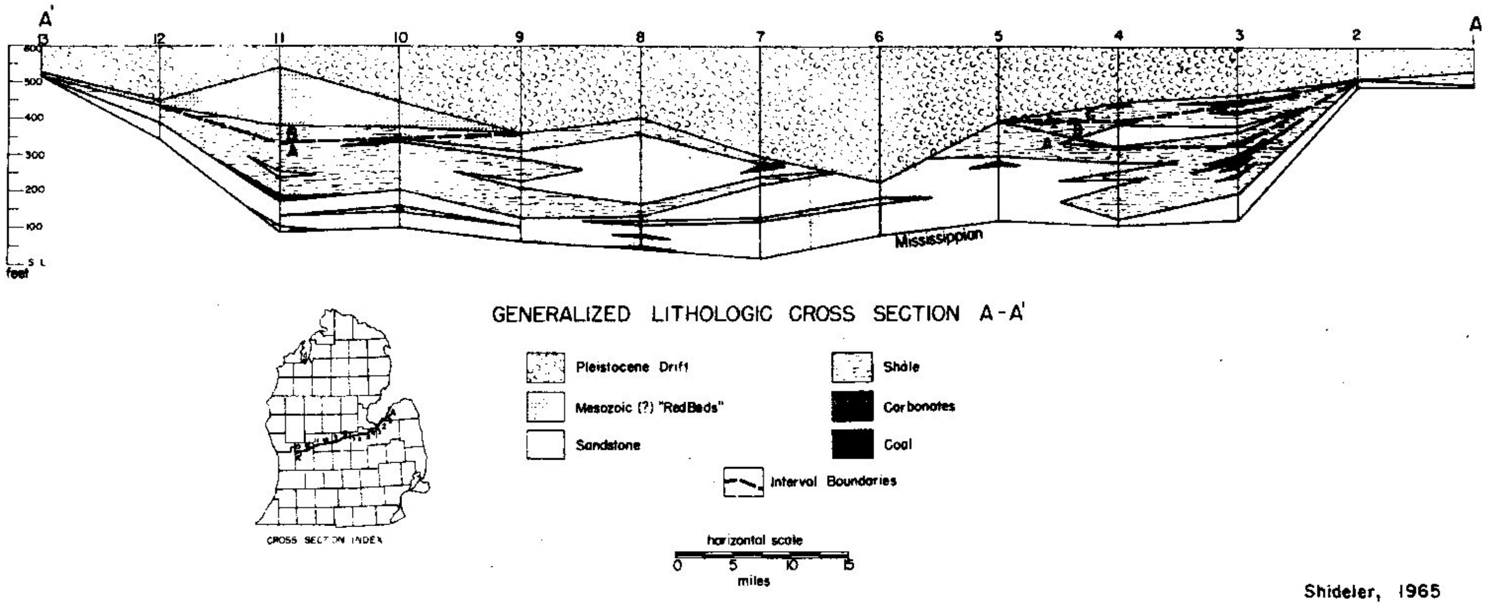

Figure 8 – Generalized Lithologic Cross Section A-A'

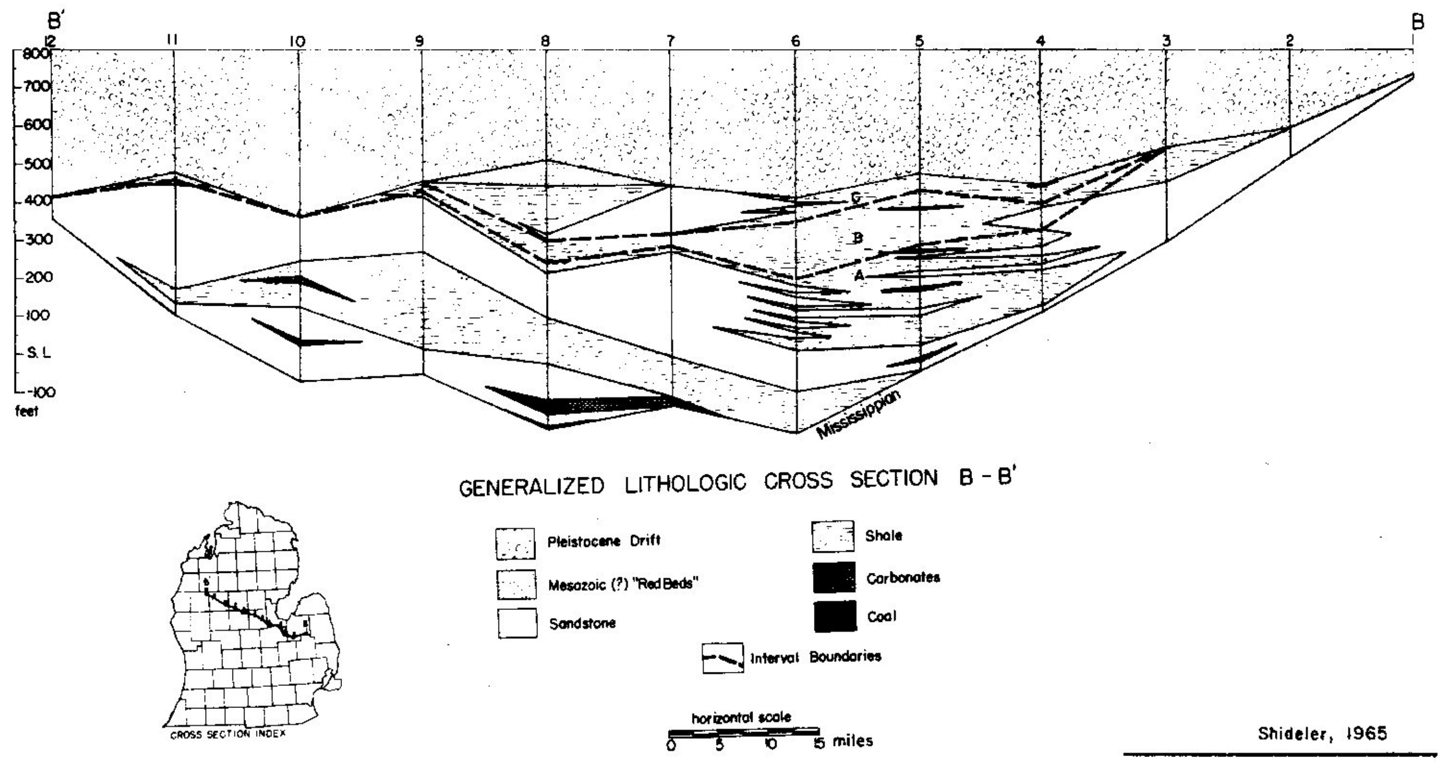

Figure 9 - Generalized Lithologic Cross Section B-A'

future search for coal can be confined to the southern and eastern parts of the basin.

Stratigraphy in Coal - Bearing Sequences

As noted by previous workers, in the coal - bearing areas the sedimentary conditions fluctuated rather rapidly, so that very few beds persist laterally for any distance. The most persistent are probably shaley limestones or limestones representative of more quiet periods of deposition when the land was low in relationship to sea level.

Names have been applied to coal beds in some of the more important districts. However, as noted by Cohee (1950) it becomes difficult to use these terms in a precise manner under conditions in which beds merge or split laterally. Also, in the absence of identifiable marker beds it becomes difficult to decide whether beds in nearby districts are indeed exact equivalents.

Any future coal exploration effort must be mindful of this great variation in stratigraphy and of the problems in dealing with such geological situations.

Present Work

Because Michigan coal occurs in such a discontinuous manner, future exploration and production in the Michigan coal basin will necessarily rely on detailed information concerning distribution and thickness of local occurrences. Specific information of this type accumulated to date is presented on a series of maps on two different scales:

1) Coal deposits by county; scale = 1" = 1 mile. These are up - dated versions of the maps by Cohee, et al (1950). The maps show the coal seams and ~i:iTI holes in areas of more detailed information. Estimates of measured, indicated, and inferred coal tonnages are made in the areas encompassed by these county maps.

Particular attention should be paid to the reserve - category significance of pattern in the map legend (Figure 1): (a) All of the measured reserves are designated by the patterns indicating the distribution of the Uppermost, Intermediate, and Lowermost beds except that this pattern also includes a few areasWThF4ess than 28 inches of coal. We have attempted to exclude such areas from our reserve calculation. (b) The dashed line indicating "Possible extent of coal bed (this work)" designates indicated - category reserves, but again includes in a few places beds with a thickness less than 28 inches.

2) Coal basin, general; scale = 1:500,000. On this map are assembled all drill holes and old mine locations in outlying areas where data is relatively scant. More drilling will be required at some of the sites before one can determine the quantity and quality of the existing coal.

Map Legend

	Uppermost Bed (Cohee Et All, 950)
	Intermediate Bed (
	Lowermost Bed I
	Minedoutarea ("
	Possible Extent Of Coal Bed (This Work)

Figure 10. Map legend used in this report.

3) Glacial drift thickness map; scale = 1:500,000. The information on this map has been derived from several sources. The outcrops are from Akers (1938). The detailed thickness contours in the southern part in Clinton, Easton, and Ingham Counties are by Van Lier et al (1973). Information for the rest of the area was compiled during this work. It was deemed more reliable to indicate the depths in the northern portion, where drill hole density is not very great, by maximum and minimum values, rather than to attempt to locate contours. It should be noted that probably in any area the thickness of overburden can vary by twenty - five percent of the value within perhaps a half a mile. Thus, the map is designed to give some indication of the severity of the overburden problem rather than providing precise information on it.

4) Because of limitations of map scales, but more specifically of time, it was not possible to plot the positions of the numerous holes which had intersected no coal. It is recognized that this negative data is valuable, but very early in the work we had to decide against acquiring it.

Basis for Estimation of Michigan Coal Reserves

Sources of Information

Because with very few exceptions the coal bearing formation is covered completely by glacial deposits, the bulk of information is necessarily taken from drilling logs. The Cohee report of 1950, a valuable foundation for the present work, was based on "more than 2500 logs of coal test test - wells, numerous mine maps, and several hundred coal analyses in the files of the Robert Gage Coal Co., together with several hundred sets of drill cuttings from exploratory wells for oil and gas, and a considerable number of mine maps from areas of former active mining, in the files of the Michigan Geological Survey" (p. 5). Since 1950 a significant amount of drilling data in the form of water, oil, and coal - test well logs has accumulated in the Michigan Geological Survey file, and this new information is the basis for the present work. In addition, several geological reports which are referenced in the bibliography were reviewed in the search for additional data on Michigan coal deposits.

In 1974 - 75, one small surface coal mine was in operation at Williamston, Michigan. This, and the pits near Grand Ledge, are the only localities where coal beds can be studied through direct observation, because none of the old mines are available for study. All are flooded, and of the waste dumps, many have become overgrown, or are the sites of farm buildings, or have been removed for land fill (Figures 11, 12, and 13). Elsewhere former pits are the sites of golf courses, or have become occupied by houses. It is not uncommon for local residents to have no knowledge, or for the local landscape to provide no evidence, of mines that were active around the turn of the century.

The sulfur analyses of Michigan coals used in this report are from the work of Andrews and Huddle (1948). We note from our comparison of data that this source was used also for sulfur content of Michigan coals in the reserve base estimate in Information Circular 8680. In the Appendix (Tables 4, 5) we have compiled all of the other available analyses, including a recent one of coal from the Williamston Mine. Most of the analyses are of dry coal, rather than of in situ samples, as can be seen from their low moisture content.

Reliability of Drill Log Data

Some of the available drilling logs are specifically from coal - borings and hence represent highly reliable data, of the kind presented in the Cohee paper. However, many of the drillers' logs filed in recent years record work done in searching for water or oil. In that their primary objective was not to gather information about coal, commonly the logs provide only fragmental or incidental data about the coal - bearing formation. In addition, it is difficult for drillers to distinguish between coal and black shale, especially carbonaceous black shale, so that some of their identification can be suspect. Because of these facts the writers treat conservatively all coal data derived from oil well and water well drillers' logs. However, these logs do provide good information on the depth of glacial overburden.

Limitations to Mining Imposed by Oil Wells

It is obvious that reasons of safety will preclude the mining of coal from around the casing of a producing oil well. Thus, our map data can be contradictory in those instances in which cuttings from an exploratory oil bore hole disclosed a new coal occurrence. One should check into possible Federal or State regulations governing such circumstances.

Figures 11, 12 and 13 not included in this version

Method of Estimating Reserves

The format established by Cohee (1950) for estimation of reserves in Michigan conforms to that used by the U.S.B.M. for establishing their reserve base. Thus Cohee's data continues to be usable. Cohee describes his method as follows:

"The irregular thickness and erratic distribution of coal in Michigan is generally due to the lensing of the beds and locally to preglacial cutouts. Therefore, accurate estimates of reserves can be made only where detailed information is available. The occurrence of coal in isolated wells and surface explosures cannot be relied upon as evidence of the existence of continuous beds, as is generally true in other areas. Nor is the absence of coal in a single well sufficient evidence to indicate its absence in more than a small area, for some test wells show no coal although they were drilled in areas surrounded by coal. Because of the lenticular nature of the coal beds, it was considered advisable to confine the estimates of measured, indicated, and inferred coal to areas in which closely spaced drilling for coal had been done, and for which drill hole records and mine information were available.

The assumptions and procedures used in computing the coal reserves of Michigan, which of necessity were more rigid than those employed in other states where the coal beds may be assumed to have a reasonable continuity, are summarized briefly below:

Measured coal1 is coal for which tonnages are computed from measurements taken in mine workings and drill holes. The points of observation and measurement are so closely spaced, and the thickness and extent of coal so well defined, that the computed tonnage is judged to be accurate within 20 percent or less of the actual tonnage. The outer limit of a block of measured coal is drawn within a few hundred feet of the outermost points of positive information, which conservative assumption is necessary to define measured coal in Michigan because of the known lack of continuity of the beds. From the drill hole and mine information the area underlain by each coal bed more than 14 inches thick was outlined. In most of the areas of concentrated information more than one bed was present, and it was necessary to establish correlations between holes on the basis of the thickness of the individual beds, the intervals between beds, and the lithology of the enclosing rocks. The weighted average thickness of each bed was then determined, all partings more than 3/8 - inch being excluded, and the reserves in each individual bed computed. For purpose of calculation the coal in the ground was assumed to weigh 1800 tons per acre - foot.

No coal beds over or under a mined out area are shown on the maps, although it is known that coal is present both above and below such areas in some places. It is considered that this coal, if it is of minable thickness, could be recovered with difficulty, if at all, and it was therefore not included in the estimates.

Indicated coal is coal for which tonnage estimates are based primarily on thickness measurements in isolated drill holes. It is assumed that the thickness of coal observed in the drill holes is representative of the area covered by a circle with a radius of 1/8 mile, the drill hole being the center. Indicated and inferred categories are shown in Table 2.

Inferred coal is coal for which tonnage estimates are based on the isolated drill holes that were also used on computing indicated reserves. The general rule was to limit inferred coal to the area lying outside the circle of 1/8 mile radius containing indicated reserves and inside a circle of 1/4 mile radius. In some areas, however, where drill holes are more than 1/2 mile, but less than 1 mile apart, and the evidence indicates that the coal is fairly persistent, some reserves have been inferred to be present between the holes (Gohee, 1950, p. 5)."

Reserve base is described in the U. S. Bureau of Mines Information Circular 8680 (1975, p. 29) as follows:

"Include beds of bituminous coal and antracite 28 inches or more thick and beds of subbituminous coal 60 inches or more thick that occur at depths to 1000 feet. Include also thinner and/or deeper beds that presently are being mined or for which there is evidence that they could be mined commerically at this time. Include beds of lignite 60 inches or more thick that can be surface mined - - generally those that occur at depths no greater than 120 feet. Also, it includes only coal from measured and indicated categories of reliability" (Table 3).

For Michigan then, the calculated reserve base is the sum of the measured and indicated tonnages for those beds greater than 28 inches thick. The reserve base is subdivided further into the categories of strippable and non - strippable coal. Michigan's strippable reserve base, as defined by the U. S. Bureau of Mines, is that part of the total reserve base which has less than 100 feet of overburden and is minable by stripping methods.

Tonnage estimates for these categories are presented in the Appendix. It should be noted that because tonnage estimates in the indicated category have been revised upward based on our new information, the reserve base estimates presented here are slightly higher than those published in U. S. Bureau of Mines Information Circular 8680. Some of this previously unreported indicated coal is located in Midland County, which was not included in the earlier Michigan's reserve base estimate.

Acknowledgements

The compilation of most of the data in this report presented in the form of maps and tables, as well as the calculations of reserves, are the work of my able and capable Graduate Research Assistant, Edwin J. Welch, who at one time considered basing a thesis on this study. The senior author has confirmed the reliability of all phases of this work, and filled out its scope. Thus, any errors in content or in interpretation are those of the Principal Investigator, the senior author.

Some of the tedious compilation of data from voluminous drill records was done by Peter A. Fitzgerald. All of the drafting was done by Mr. P. H. Ostlender, and the typing by Miss J. Erickson. Mr. R. C. Brainard, Jr., of the Berwind Land Company provided a recent analysis of Williamson coal. It was possible to accomplish this work because of the full cooperation of the Michigan Geological Survey, particularly of Harry 0. Sorenson and W. A. Walden. To all of the above Ed Welch and I extend our sincere thanks.

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Maps 4A, 5A, 6A, 7A, 8A, 9A, 10, and 10B are not included in this version

Appendices

TABLE 1 - Measured Coal in Michigan in Beds Greater Than 28 Inches Thick as of June]., 1976, by Counties and Townships (in millions of short tons) (after Cohee, 1950).

	50 to 100 Ft.	Greater Than 100	Township
Townshio	Overburden	Ft. Overburden	Total
Bay County			
T13N, R4E	0.47	5.49	5.96
T13N, R5E	--	0.22	0.22
T14N, R3E	7.57	1.37	8.94
T14N, R4E	0.18	6.95	7.13
T14N, R5E	0.11	1.14	1.25
T15N, R3E		2.01	2.01
T15N, R4E		0.76	0.76
T16N, R3E		16.19	16.19
County Totals	8.33	34.13	42.46
Genesee County			
T7N, R6E		1.78	1.78
T7N, R7E		5.16	5.16
County Totals		6.94	6.94
Huron Count			
T15N, R9E		6.38	6.38
County Total		6.38	6.38
Saginaw County			
T9N, R2E	0.35	0.63	0.98
T9N, R3E	1.30	0.53	1.83
T10N, R3E	--	4.37	4.37
T11N, R3E	0.19	5.98	6.17
T11N, R4E	--	3.23	3.23
T12N, R4E		2.04	2.04
T12N, R5E		0.05	0.05
T12N, R6E		0.25	0.25
T13N, R3E		2.62	2.62
T13N, R4E		1.07	1.07
County Totals	1.84	20.77	22.61
Shiawassee County			
T7N, R4E	0.03	--	0.03
T8N, R3E	--	0.34	0.34
T8N, RIIE		3.65	1.65
County Totals	0.03	1.99	2.02
Tuscola County			
T13N1 R7E		0.73	0.73
T13N, ROE		0.04	0.04
T14N, R7E		2.84	2.84
T14N, R8E		8.49	8.49
T14N, R9E		2.06	2.06
T15N, R8E		1.40	1.40
County Totals		15.56	15.56

TABLE 2 - Indicated and Inferred Coal Estimates for Michigan, as of June 1, 1976 by Counties and Townships (after Cohee, 1950). (In Millions of Short Tons) Indicated Coal = Ind =Greater than 28 inches thick; Inferred Coal = Inf = Greater than 14 inches thick *

Township	Ind.	Inf.
Bay County		
T13N, R4E	0.44	0.98
T13N, R5E	0.03	1.12
T13N, R6E	1.41	4.88
T14N, R3E	0.79	2.15
T14N, R4E	5.93	13.36
T14N, R5E	4.51	10.72
T15N, R3E	0.25	0.62
T15N, R4E	0.22	0.58
T16N, R3E	0.56	1.61
County Totals	14.14	36.02
Genesee County		
T7N, R7E	0.09	0.20
T8N, R5E	0.81	2.44
County Totals	0.90	2.64
Huron County		
T15N, P9E	0.08	0.19
Midland County		
T15N, R2E	0.60	1.79
Saginaw County		
T9N, R2E	0.45	1.07
T9N, R3E	0.21	1.25
T10N, R2E	0.07	0.60
T10N, R3E	1.00	3.12
T11N, R2E	--	0.95
T11N, R3E	0.78	2.53
T12N, R4E	0.16	0.47
T12N, R5E	2.15	6.15
T12N, R6E	1.05	4.14
T13N, R3E	0.23	0.47
T13N, R11E	0.22	0.49
T13N, RSE	0.20	0.59
County Totals	6.52	21.83
Shiawassee County		
T7N, R3E	0.30	0.89
T7N, R4E	0.39	0.76
T8N, R3E	0.32	0.96
T8N, R11E	0.52	1.69
County Totals	1.53	4.30
Tuscola County		
T13N, R7E	0.50	1.45
T13N, R8E	1.89	4.98
T13N, R9E	0.16	0.48
T13N, R10E	0.33	0.99
T14N, R7E	0.41	1.59
T14N, R8E	1.71	4.67
T14N, R9E	0.68	2.00
T15N, RSE	1.08	1.74
County Totals	6.76	17.90

*Thicknesses of coal seams in the inferred category are uncertain at best.

Table 3. Bituminous Coal Reserve Base by State, County Red, Thickness, Type Of Mining, and Sulfur Range (Million Short Tons)

260 Michigan -

RESERVES BY SULFUR RANGE, PERCENT X = NO. OF ANAL Y = AVG S %

THICKNESS	< .4	.5-.6	.7-.8	.9-1.0	1.1-1.4	1.5-1.8	1.9-2.2	2.3-2.6	2.7-3.0	> 3.0	UNKNOWN	TOTAL	X Y
COUNTY:	017 BAY												
BED:	799												
DEEP >28	.00	.00	.00	3.00	9.05	12.44	12.55	9.16	5.27	3.88	1.03	56.60	32 1.9
STRTP >28	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	
TOTAL	.00	.00	.00	-	3.00	9.05	1?.44	12.55	9.16	5.27	3.88	1.03	56.60
COUNTY:	TOTAL												
DEEP >28	.00	.00	.00	3.00	9.05	1?.44	12.55	9.16	5.27	3.88	1.03	56.60	32
STRIP >28	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.oC	
TOTAL	.00	.00	.00	3.00	9.05	12.44	12.55	9.16	5.27	3.88	1.03	56.60	
COUNTY:	049 GENESEE												
BED: 799													
DEEP >28	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	7.84	7.84	
STRIP >28	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	
TOTAL	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	7.84	7.84	
COUNTY:	TOTAL												
DEEP >28	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	7.84	7.84	
STRIP >28	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	
TOTAL	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	7.84	7.84	
COUNTY:	063 HURON												
	BED: 799												
DEEP >28	.00	.00	.00	.00	.00	.00	.00	.00	.00	6.46	.00	6.46	4 8.8
STRIP >28	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	
TOTAL	.00	.00	.00	.00	.00	.00	.00	.00	.00	6.46	.00	6.46	
COUNTY:	063 HURON												
	RESERVES BY SULFUR RANGE. PERCENT	NO. OF AVG											
COUNTY:	TOTAL												
DEEP >28	.00	.oo	.00	.00	.no	.00	.00	.00	.00	6.46	.00	6.46	4

THICKNESS	< .4	.5-.6	.7-.8	.9-1.0	1.1-1.4	1.5-1.8	1.9-2.2	2.3-2.6	2.7-3.0	> 3.0	UNKNOWN	TOTAL	X Y
STRIP >28	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	
TOTAL		.00	.00	.00	.00	.00	.00	.00	.00	.00	6.46	.00	6.46
COUNTY:	145	SAGINAW											
	BED:	799											
DEEP >28	.00	.00	.00	1.59	4.75	6.38	6.07	4.16	2.24	1.83	.2.09	29.13	47 1.6
STRT~ >28	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	
TOTAL	.00	.00	.00	1.59	4.75	6.38	6.07	4.16	2.24	1.83	2.09	29.13	
COUNTY:	TOTAL												
DEEP >?B	.00	.00	.00	1.59	4.75	~.38	6.07	4.16	2.24	1.83	2.09	29.13	47
STRIP >28	.00	.“O	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	
TOTAl	.On	.00	.00	1.59	4.75	6.38	6.07	4.16	2.24	1.83	2.09	29.13	
COUNTY:	15~ SHIAWASSEE												
	bED: 799												
DEEP >?8	.00	.00	0.42	2.22									
			.00	.00	.22	.35	.42	.36	.23	.18			22 2.0
STRTP >28	.00	.00	.00	.00	.07	.11	.13	.11	.07	.05	0.77	1.33	
TOTAL	.00	.00	.00	.00	•~9	.46	.SS	.47	.30	.23			
	1.19	3.55											
COUNTY:	TOTAL												
DEEP >28	.00	.00	.00	.00	.?2	.35	.42	.36	.23	.18	0.42	2.22	22
STRIP >?8	.00	.00	.00	.00	.07	.11	.13	.11	.07	.05	0.77	1.33	
TOTAL		.00	.00	.00	.00	.?9	.46	.55	.47	.30	.23		
	1.19	3.55											
COUNTY:	157 TUSCOLA												
BED: 799													
DEEP >28	.00	.00	.00	.00	.00	.00	.00	2.01	9.27	8.43	2.61	22.32	6 2.9
STRIP >28	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.fl0	
TOTAL	.00	.00	.00	.00	.00	.00	.00	2.01	9.27	8.43	2.61	22.32	
COUNTY:	TOTAL												
DEEP >28	.00	.00	.00	.00	.00	.00	.00	2.01	9.27	8.43	0.48	22.32	6
STRIP >28	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	
TOTAL	.00	.00	.00	.00	.00	.00	.00	2.01	9.27	8.43	0.48	22.32	
COUNTY:	MIDLAND												
	BED:	799											
DEEP >28	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	0.60	0.60	
STRIP >28	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	0.00	0.00	
TOTAL	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	0.60	0.60	
STATE TOTAL													
DEEP >28	.00	.00	.00	4.59	14.02	19.17	19.04	15.69	17.01	20.78	12.46	125.17	
STRIP >28	.00	.00	.00	.00	.07	.11	.13	.11	.07	.05	0.77	1.33	
TOTAL	.00	.00	.00	4.59	14.09	19.28	19.17	15.80	17.08	20.83			
	13.23	126.50	0										

(includes only coal from measured and indicated categories of reliability) (distribution may not add to total because of rounding) from u.s.b.m. ig-8680, updated, 1976

(includes only coal from measured and indicated categories of reliability) (distribution may not add to total because of rounding) 260 michigan table 3 . bituminous coal reserve base by state, county red, thickness, type of mining, and sulfur range (million short tons) (includes only coal from measured and indicated categorifs of reliarility) (distrihution may not add to total because of rounding) - from u.s.b.m. ic-8680, updated, 1976

TABLE 4 - Unpublished Coal Analyses (from Michigan Department of Natural Resources) Proximity % Ultimate %

County	Mine	Years of Analysis	File No	Moisture	Volatile Matter	Fixed Carbon	Ash	Sulfur	Hydrogen	Carbon	Nitrogen	Oxygen	Calorific B.t.u.		
Bay															Comments
	Wolverine #3	1908	8	4.8	38.5	45.0	11.7	3.0					12,649		
	Robert Gago #7		3	8.4	34.9	54.0	2.7	.9					12,970		Air dried
	West Bay City		4	8.3	35.7	51.0	5.0	1.1					12,550		Air dried
			15	5	59.8	41.7	13.7	6.7	4.6	62.3	1.2	8.8	12,012		
Calhoun															
	Albion	1922	22	9.6	41.7	42.9 15.4	12,870								
Huron															
	Sebawaing														
	Standard Mine		14	6.1	39.6	46.1	8.3	5.7	5.3	68.1	1.5	5.2	12,714		
Ingham															
	Williamston	1936	12	2.2	25.7	23.9	48.2	3.6					13.958		
		1936	13	2.4	26.9	24.3	46.2	2.39					13,688		
		1975	16	15.6	.35	48.1	1.3	.78					12,381		From Berwin Land Company
Midland															
	Midland	1906	7	2.0			5.6	1.4					13.656		
Saginaw															
	Garfield	1912	9	3.6	42.8	42.9	10.7	2.1					12,260		NW Car NW'~ Sec 26
		1912	10	6.4	40.5	43.0	10.1	3.7					12 300		Garfield Twp. ~ow~r seam)
		1912	11	5.4	41.9	43.7	9.0	3.6					12,600	J	~ 26-27w Garfield Twp.
	Pare Marquette	1899	17	10.1	35.1	54	2.7	1.1	4.7	71.1	1.4	8.8	12,726		
	Standard Mine	1899	18	10.7	33.6	54	1.9	1.0	4.9	71.7	1.4	8.5	12,868		
	Garfield	1906	20	1.3	43.9	45	9.5						13,416		
	Saint Charles														
	Somers #1	1899	19	7.8	34.7	52.9	4.9	1.0	4.4	71.4	1.4	9.3	12,636		
Van Buren															
	Geneva Twp.	1944	21	2.6	48.9	43.9	4.6								In Glacial Drift?
	Sec. 30														
	Gannett Farm														

Table 5 - Average analyses of samples from michigan coal. MIne~l

	Mine	Moisture Volatile	Fixed	Ash	Sulphur	Air Dry	B.t.u.	Soifening reps1'.	
		Matter	Carbon			Lass		(Oep.rees F.)	
Community	Composite aatttpla	6.2	40.1	46.8	6.9	3.8	5.3	12,810	
Bay Co.	from 2 locations								
Albion	Composite sample	3.8	43.8	43.4	9.0	6.9	7.7	12,610	
Calhoun Co.	from 2 locations								
Cooper	(Owosso) Composite sample	4.9	38.1	43.9	13.1	3.2	7.1	12,010	
Shiawassee	from 2 locations								
Big Chief #8	Composite sample	6.3	36.5	49.9	7.3	1.3	4.4	12.650	
St. Charles	from 3 locations								
Saginaw									

	Mine	Moisture Volatile	Fixed	Ash	Sulphur	Air Dry	B.t.u.	Soifening reps1'.	
Same	Tipple sample. One	6.3	34.7	47.4	11.6	1.1	5.5	11,940	2260
	clays run of mine coal								
Same	Tipple sample. Washed	7.6	34.8	51.3	6.3	0.9	9.2	12.550	2260
	slack. One days run								
R.	Gage #7	Composite samples	8.0	35.2	52.1	4.7	1.3	5.2	12,670
Bay Co.	from 3 locations								
Same	Tipple sample; 50%	9.8	34.9	48.7	6.6	1.3	2.8	12,240	2180
	steam lump; 50% dome-								
	stic lump. One days run								
Same	Washed slack. One days	8.3	35.3	49.5	6.9	1.0	10.0	12,310	2260
	run								
Sitinwassee	Composite sample	4.2	35.8	53.5	6.5	1.4	7.3	13,040	
Saginaw Co.	of 3 locations								
Same	Tipple sample 3"	6.1	35.9	53.6	4.4	1.2	4.8	13.150	2240
	lump. One days run								
Same	Tipple sample domestic	~5.6	37.1	54.0	3.3	1.1	5.9	13,380	2010
	washed nut. One days run								
Same	Tipple sample washed	4.9	35.7	55.1	4.3	1.0	12.3	13,330	2155
	steam nut & slack.								
	One days run								
Uncle Henry	Composite aanple	4.9	34.2	55.0	5.9	1.4	6.6	13,090	
Saginaw Co.	from 3 locations								
Uncle Henry	Tipple sample of lump	7.3	34.8	53.8	4.1	1.3	4.4	12,970	2200
Saginaw Co.	(3" screen). One days								
	ruts								
Uncle Henry	Tipple sample of washed	2.0	36.6	56.2	5.2	1.3	8.7	13.430	2300
Saginaw Co.	domestic nut. One days								
	run								
Uncle Henry	Tipple sampla of washed	1.5	35.1	56.4	7.0 . 1.3	17.5	13,270	2340	
Saginaw Co.	steam nut and slack. One								
	days run								
What Cheer	CospoCire- sample	7.3	37.3	48.0	6.4	2.?	3.7	12,490	
Cenesee Co.	from 2 locations								
Wolverine #2	Composite sample	2.1	39.1	52.5	6.3	3.2	10.5	13,250	
Bay Co.	from 3 locations								
Tipple Sample	Tipple sample of 3"	1.8	39.6	54.1	4.5	2.7	10.6	13,570	2170
I tmsp passing 3" screen									
Tipple Sample	ripple sample of	1.4	39.1	54.2	5.3	2.5	12.6	13,560	2025
	washed domestic nut								
Tipple Sample	Tipple sample of washed	1.2	36.5	56.1	5.7	2.0	18.3	13,500	2190
steam nut and sslack									
Willianston	Nine run	4.5	37.0	53.0	5.5	2.0		12.500	
Clay Pruds.									
Inghan Co.									

End of file